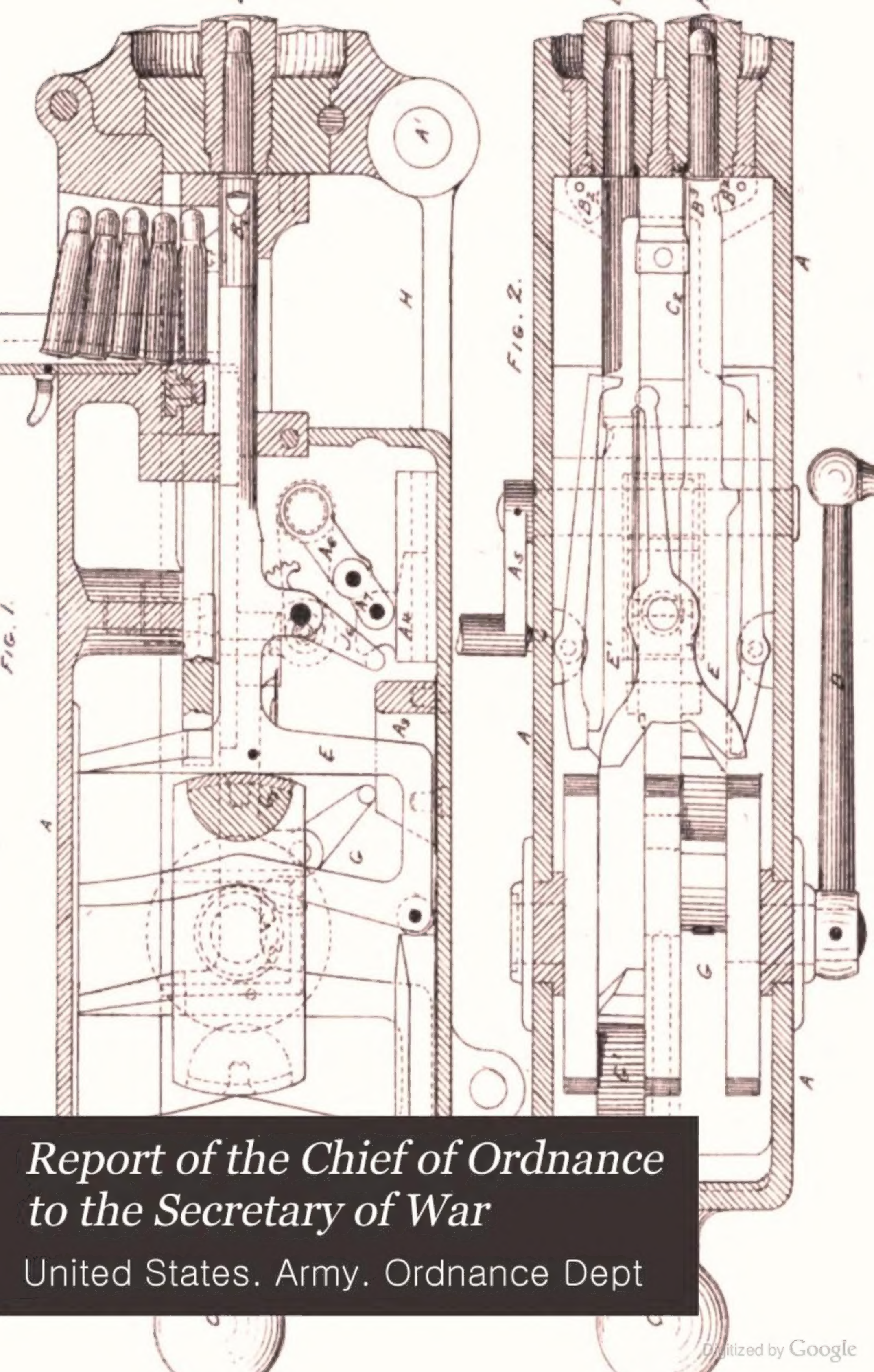
FIG. 1.

FIG. 2.

Report of the Chief of Ordnance to the Secretary of War

United States. Army. Ordnance Dept

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BRIG. GEN. S. V. BENÉT,

CHIEF OF ORDNANCE, U. S. ARMY.

ANNUAL REPORT

OF THE

CHIEF OF ORDNANCE

TO THE

SECRETARY OF WAR

FOR THE

FISCAL YEAR ENDED JUNE 30, 1884.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1884.

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REPORT OF THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 15, 1884.

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1884, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the Department during the year were as follows, viz:

Amount in the Treasury to the credit of the appropriations on June 30, 1883	$629,701 47
Amount in the Treasury not reported to the credit of the appropriations on June 30, 1883	5,966 57
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1883	227,814 45
Amount of appropriations for the service of the fiscal year ended June 30, 1884	1,981,494 80
Amount refunded to ordnance appropriations in settlement of accounts during the year ended June 30, 1884	16,264 99
Gross amount received during the fiscal year ended June 30, 1884, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island and Pacific Railroad Company; from powder and projectiles (proceeds of sales); from sales of condemned stores; from testing machine, and from all other sources not before mentioned	125,888 25
Total	2,987,130 53
Amount of expenditures during the fiscal year ended June 30, 1884, including expenses attending sales of condemned stores, powder, and projectiles, &c	2,015,255 58
Amount deposited in Treasury during the fiscal year ended June 30, 1884, as proceeds of sales of Government property	92,540 09
Amount transferred from ordnance appropriations in settlement of accounts during the fiscal year ended June 30, 1884	81
Amount turned into the surplus fund on June 30, 1884	249,290 49
Amount in Government depositories to the credit of disbursing officers and others on June 30, 1884	209,007 50
Amount in the Treasury not reported to the credit of appropriations on June 30, 1884	7,545 43
Amount in the Treasury to the credit of appropriations on June 30, 1884	413,490 63
Total	2,987,130 53

STATIONS AND DUTIES.

The stations and duties of the officers of the Ordnance Department are as follows: Four at the Ordnance Office; thirty-six at the arsenals, armory, agency, and powder depots; nine on the Ordnance Board and at the foundries; seven at the several military headquarters and ordnance depots; four at the Military Academy; one under the orders of the Secretary of the Interior; one in the Life-Saving Service, under the Secretary of the Treasury.

The Ordnance Department provides the armament for our sea-coast defenses, and arms and other ordnance stores for the Army, the militia, the Marine Corps, all other Executive Departments to protect public money and property, and the forty colleges authorized by law to receive them for instruction. These ordnance and ordnance stores must be of the best quality and of superior workmanship, to render them most effective as war material, and modern invention and improved mechanical methods must be carefully studied and utilized.

The report of the operations at the Rock Island Arsenal is submitted. The erection of shops and storehouses has been conducted economically and thoroughly, and the estimates for the prosecution and completion of the same should receive favorable consideration. The last appropriation of $10,000 for the general care, preservation, and improvement, for building roads, painting buildings, bridges, &c., is not deemed adequate to the necessities of the arsenal. In this connection Colonel Flagler remarks in his report:

> "The utmost that is possible has been done to economize. It is nearly impossible that some improvement of grounds should not be carried on in connection with the construction of buildings in order to utilize material excavated, finish grounds around the buildings, and furnish needed improvements for use in carrying on other work. Besides this, the buildings, roads, and other improvements are now of such magnitude that they require fully ten times as much for their proper care and preservation as they did thirteen years ago, at which time the appropriation for this work was double that which has been allowed in the past few years.
>
> "I know of no better method of exhibiting this than by comparison. The extent of the work that ought to be done, to keep in good order and repair streets, avenues, grounds, large bridges, shores of island, railroads, gutters, walks, sewers, waterworks, and the dams and gates and other constructions pertaining to the water-power, is equal to the work of a similar kind done in a city of 10,000 inhabitants. In addition to this, the buildings and many other constructions taken care of by private owners in a city must be kept in repair."

The reasons here given are strongly in favor of larger appropriations for this object. The work of care and preservation is a continuous one, never ending and never completed, and this our largest Government establishment deserves to be kept in such excellent condition as to reflect credit on the country.

SMALL-ARMS.

During the fiscal year ended June 30, 1884, 35,133 rifles, carbines, and shot-guns have been manufactured at the National Armory. Much has also been done in repairing arms, providing spare parts, making swords and sabers and miscellaneous supplies, and manufacturing the Chaffee-Reece magazine gun. It is but fair to record that the well-deserved reputation of the Armory, for the superior design and finish of its products, has been maintained, and that Lieutenant-Colonel Buffington has administered the affairs of that establishment with marked ability and success.

The Lee, Chaffee-Reece, and Hotchkiss magazine guns, recommended by the Board in September, 1882, to be issued to the Army for trial have, after the delays incident to the production of new arms requiring special tools and machinery, been received from the contractors and completed at the Armory, and are now ready to be issued to the Army for trial by the troops.

For some time efforts have been made at the Armory to perfect the rod bayonet and attachment, dispensing with the ordinary triangular bayonet. The rifles first provided with the rod bayonet were defective in design and failed to give satisfaction. The new arrangement will be submitted to you at an early day. The front and rear sights of the rifle have been greatly improved, embodying new and important details which will be found of value in long-range firing, and it is hoped that they will satisfy a much-needed want of the Army.

An estimate has been submitted for a milling shop for the National Armory to cost $30,000. It is to be a fire-proof structure, two stories and basement, and about 275 by 35 feet, to replace the present old building, which is unfit and dangerous, and in case of fire would destroy the principal machinery, and suspend operations for many months at the Armory. The appropriation asked for is earnestly recommended.

REWARDS FOR TARGET PRACTICE.

The gold and silver medals, as rewards for successful marksmanship in the different Army contests, including the skirmishers' medals for Department, Division, and Army teams, recently added to the list, have been supplied to the several headquarters in advance of the date of contests, that they might be delivered to the successful contestants on the spot.

The sharpshooters' bronze crosses and the marksman's pins, also authorized by G. O. No. 12, of February 20, 1884, have been made, and are being distributed to the Army.

The liberality of the War Department in providing so many artistic and costly medals and other rewards, for successful efforts on the part of officers and soldiers, has been a powerful and healthy stimulus to the steady improvement of the Army in skillful marksmanship. Being an expert shot leaves nothing wanting to the perfection of the modern soldier. The bullet that unerringly attains its object fully repays all the expense and labor that makes that possible.

A new work on target firing, which will embody the experiences of the Army in target practice during the past five years, is being prepared under your authority by Capt. S. E. Blunt, Ordnance Department and Chief Ordnance Officer Department of Dakota. Its completion is promised at an early day, when it will be submitted for your consideration and approval. His wide experience in charge of target practice in that military department, and his excellent record as a skillful rifle shot in many contests, assures Captain Blunt's success in the preparation of a satisfactory text-book for the instruction and guidance of the Army in this most interesting field of study and practice.

MACHINE GUNS.

The improved Gardner gun, described in the Report of the Chief of Ordnance for 1880, has this year been subjected to further trials at the Proving Ground, under the supervision of the Ordnance Board. The conclusions of the Board (see Appendix 19) are very favorable to the gun, which is pronounced to be light, compact, and simple in its structure, and to compare favorably with the Gatling gun in everything except rapidity of fire. The device for feeding is admirable, and the pasteboard box for containing the ammunition of the infantry can be easily adapted for use with this gun, which is a great advantage for a machine gun designed to co-operate with infantry fire.

The Board has recommened that some of the guns be procured for service.

ARTILLERY PRACTICE.

More than ordinary interest has been evinced in the theory and practice of gunnery by portions of the artillery branch of the service, and notably so by batteries stationed in New York Harbor, under Col. John Hamilton, commanding Fifth Artillery. His "Report of Artillery Practice" at "The Narrows," in October and November, 1883, will be found interesting and comprehensive, giving an excellent practical system which can be applied in other harbors and roadsteads. His report is submitted in the hope that its publication may excite some such degree of interest and emulation in the study and manipulation of heavy cannon as now rules the Army in rifle firing.

This report gives expression to the zeal and ability which have crowned Colonel Hamilton's endeavors with such encouraging success.

GUN FOUNDRY BOARD AND CONGRESSIONAL COMMITTEES.

In my last annual report reference was made to the "Gun Foundry Board" appointed in accordance with the act of Congress approved March 3, 1883:

> "For the purpose of examining and reporting to Congress which of the navy-yards or arsenals owned by the Government has the best location and is best adapted for the establishment of a Government foundry, or what other method, if any, should be adopted for the manufacture of heavy ordnance adapted to modern warfare, for the use of the Army and Navy of the United States, the cost of all buildings, tools, and implements necessary to be used in the manufacture thereof, including the cost of a steam hammer, or apparatus of sufficient size for the manufacture of the heaviest guns."

Its report was made to the President February 16, 1884, and was by him transmitted to Congress, February 18, 1884. The conclusions reached by the Board after full investigation of the subject here and abroad are: The establishment of Government gun factories for both the Army and Navy, and the making a permanent and liberal appropriation by Congress for the specific purpose of porviding artillery of modern types, this appropriation being a permanent one, to act as a stimulus to private steel manufacturers to enlarge their plant and make gun steel, the Government being a large purchaser. A special estimate for a permanent annual appropriation to carry out this recommendation of the Board was submitted by me, but Congress took no action thereon.

In the closing days of the last session both the Senate and House passed resolutions for the appointment of select committees of Senators and Representatives, respectively, to inquire—

> "As to the capacity of steel-producing works in the United States to make steel of suitable quality, and sufficient in quantity to furnish metal for guns of high power * * * as to the character and sufficiency of machinery and machine tools in the navy-yards, and also in private foundries and machine-shops in the United States, * * * and for manufacturing guns for the proper armament, * * * of the sea-coast defenses, * * * into the best locations in the United States for manufacturing guns, * * * and the best method of manufacturing and building the same, whether by the Government or by contract with private persons."

The field of this inquiry is large and comprehensive, and includes all that is required for a complete understanding of the subject, and the best means of providing a remedy. The condition of our coast defenses is a matter of grave concern and calls for immediate action, and I indulge the hope that before the end of the ensuing session Congress will show to the country its appreciation of these national wants by a liberal and permanent annual appropriation.

ARMAMENT OF FORTIFICATIONS.

During the past year the construction of the several experimental guns commenced in 1883, under provisions of the act of March, 1883, has progressed as rapidly as circumstances, somewhat unfavorable, would permit. Owing to the discontinuance, for a number of years, of the manufacture of cast-iron guns at the South Boston Foundry, numerous trials were requisite at the outset to work up the iron to a proper standard before the castings could be made. Later, the backwardness of foreign manufacturers in meeting their engagements for furnishing steel forgings has caused additional delay in the completion of these guns. It has now become practicable, however, to procure part of the forgings in question from the Midvale Steel Company, and an order has accordingly been given to that effect.

The 12-inch breech-loading rifle, cast-iron, has been cast, and is in such advanced stage of completion that it will soon be ready for trial.

The body for the 12-inch muzzle-loading rifled mortar has been cast and finished, and hoops of suitable quality procured from the Midvale Steel Company, and the work of hooping the mortar is now in progress at the South Boston Foundry. Prior to establishing the ***shrinkages*** to be used in the construction of this piece, it was deemed prudent to make an experiment of hooping a cylinder representing an actual section of the mortar in front of the powder chamber, by means of which it could be practically determined if the proposed ***shrinkages*** were suitable to the construction.

The Department has adopted this plan of hooping an experimental section for each new model of hooped gun, in order to compare the data derived from calculations purely, with the results obtained from direct experiment, and in that way to establish a reliable basis for the construction.

The experiments made last year with two experimental 10-inch muzzle-loading rifled mortars, obtained by shortening at the muzzle and rifling two 10-inch cast-iron smooth-bore guns, have demonstrated the practicability of employing some of our existing types of projectiles, in pieces of this type, with satisfactory results. From the same experiments a suitable character of rifling was also determined for the 12-inch mortar. This mortar should be ready for trial during the next month.

In casting the body for the 12-inch breech-loading rifle, cast-iron, lined with a wire-wrapped steel tube, an accident occurred that has proved a source of considerable pecuniary loss to the founders, and a serious set-back to the early completion of the gun. About an hour after the successful casting of the gun, the flask of the mold gave way, precipitating the superincumbent mass of molten metal into the pit, forming there when cold a solid cheese. After much labor this cheese has been removed—an operation that was much facilitated by the conical form of the pit—and the founders are now making fresh preparations for another cast. Owing to this mishap the casting of the body for the 12-inch rifle, cast-iron, hooped and tubed with steel, will follow next, since the patterns, flasks, &c., are already prepared.

The body for the 10-inch breech-loading rifle, cast-iron, wrapped with steel wire, has been cast and made ready for the application of the wire. The wire winding will be done at the Watertown Arsenal, where preparations are now being made for this purpose in consultation with, and on plans furnished by, Dr. W. E. Woodbridge.

Billets and bars for wire guns.

The billets for the wire have been procured from the Otis Iron and Steel Company, Cleveland, Ohio, and before acceptance by the Department were required to pass satisfactorily the following conditions as regards physical qualities, viz:

Tensile strength	31.5 tons per square inch.
Ultimate elongation	30 per cent.
Reduction of area	50 per cent.

The reduction of area in transverse test specimens 1.2 inches between shoulders to be at least 20 per cent., and the billets to be perfectly sound and free from flaws, cavities, or defects of any kind, and of a uniform quality throughout.

The accepted billets, weighing about 80 pounds each, have been sent to the Trenton Iron Company, Trenton, N. J., where they will first be rolled into rods one-half inch square, then annealed and drawn, without further annealing, into wire .15 of an inch square, having the corners rounded with a radius of about .01 of an inch, the ends of the wire being reversed in the process at each successive passage through the draw-plate. As a final operation the wire will be thoroughly tinned to prepare it for soldering.

The bars for the longitudinal staves of the 10-inch steel-wire breech-loading gun have also been manufactured by the Otis Iron and Steel Company, and subject to the same conditions as regards their physical qualities as the wire billets. These bars are now being annealed at the Washington Navy-Yard, after which they will be sent to the works of Jones & Laughlins, Pittsburgh, Pa., where they will be cold rolled to the size of 3.4 inches square.

Forgings of Whitworth & Co.'s steel.

The tube for the steel wire 10-inch breech-loading rifle; the tube and jacket for the steel 8-inch breech-loading rifle; the tubes for two 12-inch cast-iron rifles: two 12-inch rifle breech bushings, and four trunnion hoops were ordered of fluid pressed steel from Sir Joseph Whitworth & Co., Manchester, England, under date of May 29, 1883.

This order was accepted by cablegram under date of June 11, 1883, with an agreement to deliver all the forgings within five months' time, and by an after agreement the forgings for the 8-inch breech-loading rifle were to be delivered as soon as made. Up to the present time, nearly one year since the time of delivery agreed upon, there have been received from Whitworth & Co., only the forgings for the 8-inch breech-loading rifle and the trunnion hoops, and even these were not received until they were many months overdue, and after repeated remonstrances from the Department against the failure of the company to fulfill their engagements. After still further correspondence with Whitworth & Co., urging the prompt delivery of the balance of the forgings, and repeated assurances from the company of their speedy delivery, notice was finally sent, under date of October 2, that unless the balance of the order, and the new forgings to be substituted for the forgings already delivered but rejected by the Department as not being of standard quality, were delivered before December 1, 1884, the order would be withdrawn.

The results of tests of the gun forgings received from Whitworth & Co. under the above order, so far as tested, are exhibited in appendix 36. The trunnion hoop for the 12-inch mortar possesses very fair qualities, that for the 8-inch rifle very ordinary indeed, but it may be said on their behalf that a trunnion hoop is a difficult shape to forge.

The qualities guaranteed by Whitworth & Co. for the 8-inch breech-loading rifle tube and jacket were as follows, on specimens 2 inches in length between shoulders, viz: Oil tempered:

Elastic limit	21 tons.
Tensile strength	43 tons.
Elongation	15 per cent.
Reduction in area	30 per cent.

The above qualities to be considered as a minimum.

The physical qualities found by actual test of the 8-inch breech-loading rifle tube and jacket, made on specimens 3 inches between shoulders and taken tangentially from the breech end were as follows, viz:

	Tube.	*Jacket.*
Elastic limit	15.6 tons.	17.8 tons.
Tensile strength	37 tons.	37.4 tons.
Elongation	20.2 per cent.	22.8 per cent.

The tests of longitudinal specimens, 2 inches in length between shoulders, were scarcely better than the above, while the results from compression tests were even worse. The metal in both tube and jacket is quite irregular in quality, and only the exterior of the jacket gives any evidence of oil tempering.*

Full reports of the tests were forwarded to Whitworth & Co. about two months ago, and the forgings will be replaced by new ones.

The difficulties above recounted in procuring steel from abroad, even for experimental guns, makes manifest, without lengthy comment, the necessity for home production. It is hoped that the very pressing needs of the Department and the difficulties under which it now labors in attempting to secure suitable materials for gun construction, may be relieved through the prompt and energetic action of Congress at its next session. The steel makers of this country will not undertake the production of steel on a scale adequate to our wants, without the inducement of being fairly remunerated for their outlays; and the importance for *immediate* action on the part of Congress for holding out such inducements, by liberal appropriations, cannot be over-estimated. The truth of

---

* Since the above was written, tensile tests have been made on tangential specimens, 2 inches in length between shoulders, taken from the *muzzle* end of the 8-inch tube, with the following mean results:

Elastic limit	24.1 tons.
Tensile strength	44.5 tons.
Ultimate elongation	23 per cent.

These figures confirm the suspicions of Messrs. Whitworth & Co., as expressed in a communication to this office, that the low qualities found in the breech ends of tube and jacket were due to *overheating* in the annealing process, subsequent to oil-tempering. It was, perhaps, one of those accidents now and then almost unavoidable in steel manufacture, and in no wise affects the great reputation of Whitworth & Co., so long held and sustained, for the superior quality of their steel products.

this statement is apparent when it is considered that, even after ample encouragement has been afforded, considerable time must elapse, say two years or more, before the requisite plant can be designed, constructed, and set up, and the production of steel in masses of sufficient size and of suitable quality for gun construction can become a practical success. Then the manufacture and test of the experimental or typical guns will require at least two years more, even for the more moderate-sized calibers, before the manufacture of guns in quantity can be proceeded with. It was under a clear apprehension of these facts and a deep conviction of the importance of saving time, that the Department determined to procure if practicable, the tubes, jackets, and trunnion hoops for the first experimental guns from abroad, hoping in that way to establish a starting point in the manufacture of steel guns, and thus avoid, so far as possible, the delay that must hereafter inevitably arise when steel shall be procurable in this country, for want of some well tested and definitely established types of gun construction as standards. Thus far its efforts in this direction have been attended with little success, nevertheless it will continue to persist in its purpose, believing that the importance of the object sought fully justifies such a policy. Types of guns, of at least 8 and 10 inches caliber, should be fully established by the time that our steel makers are in a condition to furnish the steel required for such constructions, in order that there may be an immediate demand for their products.

Midvale steel hoops and breech blocks.

The steel forgings, for the guns now under construction, which the Department has been able to procure from American manufacturers—as the hoops, breech blocks, &c.—and whose production came within the capacity of existing plant, are of the very highest quality, and are an earnest of what excellence it may be expected will be attained here under larger facilities for manufacture.

The hoops for the steel 8-inch breech-loading rifle, the 12-inch muzzle-loading rifle mortar, the 12-inch rifle, cast-iron hooped and tubed with steel, most of the rings for the wire guns, and the forgings for the several breech blocks have been, or are now being, manufactured for the Department by the Midvale Steel Company, Nicetown, Philadelphia, Pa. The hoops are made from open-hearthed steel, either rolled or hammered into shape, according to their size, and afterwards oil-tempered and lightly annealed, as contemplated in the circular letter issued by the Department under date of April 3, 1883.

The results of some experiments made in 1883 with trial hoops, tempered and untempered, and the first tests made under the contract for supplying the Department with the hoops for the 12-inch mortar, gave rise to doubts as to the propriety of the treatment by oil tempering and annealing. There was evidence of a want of uniformity in the oil tempered hoop, and a deficiency in the requisite *stiffness* for the outer envelopes of a gun. The manufacture, therefore, of the 12-inch mortar hoops was suspended until some further trials and tests could be executed. But in the end the excellent qualities obtained in the hoops thus treated—oil-tempered and annealed—was fully established (see Appendix 29), and that mode of treatment was definitely adopted for all the hoops under manufacture. The physical qualities as determined from the tests of tangential specimens, 6 inches between shoulders, are as follows, viz:

Elastic limit	25 to 30 tons.
Tensile strength	45 to 50 tons.
Ultimate elongation	12 to 16 per cent.

The above figures are fully equal to the highest claimed by Whitworth & Co. for the characteristics of their steel hoops.

In this connection I desire to accord to the managers of the Midvale Steel Works the high praise they have so justly earned through their intelligent and skillful methods of working and treatment, and by their untiring perseverance in experiment and research, in attaining at so early a period an equality with the very best known standards.

The hoop required for the 12-inch breech-loading rifle, cast iron, hooped and tubed, being of dimensions too great for the existing rolling-mill at the Midvale Steel Works, it became necessary to enlarge the mill and make new rolls. These hoops are now being turned out from the mill to finish to a length of 12 inches, the finished interior and exterior diameters being as follows, viz:

	Interior diameter.	*Exterior diameter.*
Inner row	39.20	45.90
Outer row	45.90	53.70

The greater part of these hoops are now rolled, and, so far as the preliminary tests have been made, they equal in quality the smaller hoops for the 12-inch mortar and 8-inch rifle.

The forgings destined for breech-blocks, of the interrupted-screw type, were hammered endwise as well as laterally, and after being bored through were oil-tempered and annealed in the same manner as the hoops. The mean physical qualities as determined from tensile tests of tangential specimens, 3 inches between shoulders, were as follows, viz:

Specific gravity	7.8648
Hardness	20.64
Elastic limit	23.5 tons.
Tensile strength	44.2 tons.
Ultimate elongation	17.3 per cent.
Reduction in area	35.5 per cent.

The results from compression test of tangential specimens 12 inches in length were as follows, viz:

Elastic limit	21.7 tons.
Strength	28.4 tons.

Eight-inch converted rifles.

Substantial progress in the production of heavy ordnance being necessarily slow makes it expedient to utilize to the utmost any existing armament or available material on hand. The casemates and barbettes of most of our sea-coast defenses are at present adapted to the 10-inch smooth-bore cast-iron gun. The power of this 10-inch gun has been largely increased by converting it into an 8-inch rifle by means of a lining tube inserted into the bore. This converted gun has shown great endurance, and very considerable power of penetration. It has therefore been the policy of the Department for the past few years, with the approval of Congress, to manufacture annually a number of these 8-inch converted rifles to be substituted for the 10-inch guns in our forts, and until more powerful guns can be procured to replace in turn the 8-inch converted rifles. Heretofore the lining tube employed in the conversion has been of coiled wrought iron; the tubes being furnished solely by the West Point Foundry Association, Cold Spring, N. Y., and the insertion of the tubes with all later guns being through the breech. With a view of widening the field for competition, as well as of simplifying the construction, the idea was entertained that if a steel lining inserted through the muzzle could be employed both those ends would be fairly attained, and the cost of conversion be materially reduced. Accordingly, during the past year, a 10-inch gun was converted on this plan, the tube—an annealed forging from open-hearth steel—being furnished from the Midvale Steel Works.

In determining upon the physical qualities for the steel tube to be employed in such conversion, and which, for economical reasons, would be inserted loosely into the casing—with a slight play—regard was had to the qualities of the wrought-iron tubes, heretofore successfully used in like constructions. It was especially desirable that the steel should possess very considerable extensibility, even at the expense of great strength and high elasticity, in order that it might safely yield under the pressure of the powder gases until set out to a firm bearing against its cast-iron casing. The permanent extension of the metal thus produced should raise its elastic limit by the development of what has been termed the *special elasticity* of the metal; at the same time the casting, if not actually thrown upon a light tension, would form a rigid support to the further extension of the tube, and thus the gun as a whole would be in the best possible condition for resistance.

The desired qualities for the tube, it was thought, would be more readily obtained from a forging that had been annealed simply, and not oil-tempered and annealed, though the opinion of the steel makers now is that equally satisfactory results would be obtained by the latter method. The tensile tests of tangential specimens, 3 inches long between shoulders, taken from both ends of the annealed forging for the tube, gave the following mean results, which were deemed satisfactory, viz:

Elastic limit	17.2 tons.
Tensile strength	35.7 tons.
Elongation	24.3 per cent.
Contraction of area	34.6 per cent.

With metal possessing these physical qualities, the elastic limit of the tube, computed in the usual way, should be from 7 to 7½ tons, and consequently the pressure due to any charge likely to be fired from the gun would be more than sufficient to permanently *set out* the tube about the seat of the charge; with a charge of 45 pounds, probably the maximum that would be used, the permanent enlargement should extend fully half-way up the bore, at least under repeated firings. To the enlargement produced by the direct pressure of the powder gases must be added any that may be due to balloting of the projectile, &c., to a mandrelling action, so to speak, of its sabot, so that we should expect a close contact to result between tube and casing, coextensive nearly with the whole length of the bore.

The work of conversion was done at the South Boston Foundry (see Appendix 26,) and after its completion the gun was sent to the Proving Ground, Sandy Hook, N. J., and turned over for trial to the Board for Testing Rifled Cannon, &c., appointed under the act of July 5, 1884. The gun has been fired five hundred rounds and still remains in good condition, and the Board has pronounced favorably upon this mode of conversion (see Appendix 21). Bids have therefore been invited this year for furnishing the materials for, and doing the work of, converting fifty 10-inch smooth-bore guns into 8-inch rifles by lining either with a coiled wrought-iron or a forged steel tube, and that plan of conversion will be adopted which presents the greater economy.

Alterations of sea-coast carriages.

The work of adapting the carriages for the 15-inch smooth-bore guns to the increased charges now employed, as provided for under the act of March, 1883, has been steadily carried on at Watertown Arsenal; also the adaptation of the same carriage to the 11-inch muzzle-loading rifle, and the alterations of the 10-inch barbette and casemate carriages for the service of the 8-inch converted rifles. Some preparations were requisite before this work could proceed, and much of the outlay last year was for materials. As a consequence, but few completed carriages have thus far been turned out from the Watertown shops, although the character of the work done at this arsenal has been of the best quality, and reflects great credit on that establishment.

Breech-loading devices.

Of the two breech-loading devices selected under the law for test, the Mann was completed and sent to the Proving Ground, Sandy Hook, N. J., early in August. The Mann gun is of 6.5-inch caliber, and was made by lining a 10-inch smooth-bore cast-iron gun with a tube of Whitworth fluid-pressed steel, and applying the Mann breech mechanism, also chiefly made from Whitworth steel. The work of manufacture was done at the South Boston Foundry (see Appendix 25), under the personal supervision of Mr. Mann himself, with whom the contract for the gun had been made. The tube for this gun and the forgings for the breech mechanism were of superior quality, and attest to the excellence of the Whitworth steel where due care has been exercised in its manufacture. The mean physical qualities of the tube obtained in tensile tests of tangential specimens, 2 inches long between shoulders, were as follows, viz:

Specific gravity	7.866
Hardness	25.7
Elastic limit	24 tons.
Tensile strength	45.8 tons.
Ultimate elongation	16.3 per cent.
Reduction of area	31.4 per cent.

The tensile tests of specimens, 4 inches long between shoulders, taken from the steel transom or cross-head of the breech mechanism gave the following results:

Elastic limit	22.8 tons.
Tensile strength	41 tons.
Elongation	23 per cent.
Reduction of area	27 per cent.

The qualities in the forgings for the breech straps were equally as good as the above.

The trial of this gun commenced in September under the supervision of the Board for Testing Rifled Guns, Mr. Mann being in attendance and concurring in the programme pursued. The largest charges used were from 37 to 40 pounds of powder, with a projectile of 109 pounds weight. The highest recorded pressure was 27,500 pounds per square inch, the corresponding velocity being 1,735 feet; the charge in this instance was 40 pounds of powder. At the twenty-fourth round the breech of the gun was blown off, the massive steel cross-head being fractured about 3 inches from its left tenon, and with the breech screw was thrown as a single fragment 54 feet to the rear, passing through a heavy timber screen; the cast-iron breech-block proper was broken into a number of fragments. The charge used at this round was 37 pounds of powder, with a projectile weighing 109 pounds; the pressure was lost, as the pressure-gauge was blown out of the gun and destroyed, but the recorded velocity, 1,748 feet, indicated that the pressure was about the same as in previous rounds. Section 2 of the act of July 5, 1884, under which the Board for Testing Rifled Guns, of which Col. T. G. Baylor is president, was constituted, provides that hereafter all rifled cannon manufactured at the cost of the United States shall be publicly subjected to the proper test for the determination of the endurance of the same, to the satisfaction of the President of the United States, or such persons as he may select, and authorizes him to select five persons who shall be skilled in such matters; it provides further, if such guns shall not prove satisfactory they shall not be put to use in the Government service. In accordance with these provisions of the law the Board reports on the trial of the 6.5-inch Mann gun that "This gun having burst at the twenty-fourth round its endurance was not satisfactory to the Board, and hence it cannot recommend that it be put to use in Government service."

The full report of the Board and of the trial of the gun is contained in Appendix 23.

The Yates gun is of 8-inch caliber, and will also consist of a 10-inch smooth-bore cast-iron gun, suitably modified, and with the attachment of the Yates breech mechanism. The work is being done at the South Boston Foundry but has been much delayed from the difficulties experienced in procuring suitable material for this peculiar construction. The steel castings procured from the Midvale Steel Company for the breech mechanism developed, in finishing, sand holes that caused their rejection, but a second set has been procured and found satisfactory. The first tube also, obtained from Firth, of Sheffield, England, was rejected for erroneous dimensions; and a second tube has been ordered from the Nashua Steel Works, Nashua, New Hampshire.

Multicharge gun.

The firings with the Lyman-Haskell multicharge gun were discontinued after the thirty-third round on account of the development of a crack in the inner tube, that extends from a short distance in front of the foremost pocket to the muzzle of the gun. This gun is, however, being repaired by the addition of steel hoops to the chase portion surrounding the crack, and before long will be ready for further trials.

The views in full of this Department of the merits of the multicharge gun, as a high-power weapon suitable for the public service, as derived from the trial of the gun, under the personal management and supervision of Mr. Haskell, up to the time the gun was disabled, will be found in Appendix 20. Briefly speaking, the results as yet are very far from fulfilling expectations; indeed the actual power thus far realized is small in proportion to the weight of the gun, and to the weight of its charge, as compared with the results from contemporary single charge steel guns.

Steel castings.

During the past spring the Otis Iron and Steel Company submitted a proposition to the Department to furnish at their own expense a rifled gun of from 8 to 10 inches caliber, made from a steel casting and unforged, provided the Department would undertake the test of such gun. It was proposed to cast the gun, bore it, and afterwards heat it up and cool it from the interior, with the object of improving the metal and securing an initial tension, after the manner of iron guns cast on the Rodman plan.

The Department did not entertain very sanguine hopes in the success of such a project in the present state of the art of producing steel castings, but thought that if reasonably good results could be obtained, perhaps the bodies of guns might be manufactured in this way of steel instead of cast iron, and by the application of rolled or hammered hoops to the exterior add sufficient strength to make a fairly good gun. But as a preliminary step and as a means of enabling it to judge of the value of this method, it was deemed best, after consultation with the Otis Iron and Steel Company, that an experimental steel cylinder should first be cast, and after treatment in the manner proposed, be cut up and subjected to mechanical test on the machine at Watertown Arsenal. Such a cylinder was accordingly cast, and of the following dimensions:

Length	60 inches.
Exterior diameter	24 inches.
Interior diameter	6 inches.

The results of the physical tests made at Watertown Arsenal are given in Appendix 30. They show very fair qualities for the lower portion of the cylinder, but which deteriorate rapidly in proceeding upwards and become quite poor at the top—as regards uniformity, elongation, and reduction of area. An initial tension of 16,000 pounds per square inch was obtained by interior cooling. On the whole, the results were not very satisfactory, but as this was the first trial of producing a cylinder simply by casting, it must be said that the results are by no means discouraging. From the experience and knowledge now gained a much better result should be expected in a second casting, especially if as proposed by the company, fluid compression of the metal is resorted to. Could sound castings be obtained with certainty, doubtless a very fair gun would be produced by their use, without a very great outlay for plant, though experience alone can show whether if proved inferior to forged steel there would be a proportional economy in guns so made over the stronger constructions, and therefore more powerful weapons made from forged and tempered steel.

Prismatic powders.

The now well-recognized superiority of molded powders of prismatic form with a central perforation, induced the Department to consider the expediency of undertaking their manufacture in this country. To this end the Messrs. Du Pont de Nemours & Co. were communicated with, and furnished with such information regarding the construction of powder presses, and the manufacture of prismatic powder, as the Department had at its disposal. The Messrs. Du Pont readily assented to the proposition of the Department, to undertake the manufacture of such powders, and for some months past have been engaged constructing a suitable press. All the necessary arrangements for the manufacture of prismatic powders will probably be completed by the end of October.

In this connection the attention of the Department having been attracted to the remarkable results obtained abroad from the so-called Brown or Cocoa prismatic powder, of German manufacture, several samples were procured for trial with heavy guns. Samples of the same were also supplied to the Messrs. Du Pont, who now have this species of powder under investigation, and it is expected that at an early day they will be able to furnish prismatic powders giving results equally as good as have been obtained with the German Cocoa powders.

Obturating primers.

The rapid deterioration of the vent of heavy guns, in firing the large charges now in vogue, renders it indispensable that some vent-sealing device be employed to prevent the rush of gas through the vent. The most convenient way of effecting this obturation of the vent is through the action of the primer by which the piece is fired. Three forms of an obturating primer have been manufactured recently at the Frankford Arsenal, and are to be subjected to tests at the Proving Ground. Two of these primers are of the class known as friction primers, and are closely allied to the Krupp obturating friction primer; the third is an electric primer and was designed at the Frankford Arsenal.

Protection of torpedo lines.

For experiments in this direction the Department procured last year a Hotchkiss 47 mm. single barrel shoulder gun, and a Hotchkiss 53 mm. revolving cannon. Owing to delay in procuring suitable powder, and the more pressing urgency of other work, no extended trials with these guns have as yet been made; they will be taken in hand, however, early in the coming year.

A table of data respecting the Hotchkiss single barrel guns furnished by Mr. Hotchkiss is exhibited in Appendix 24.

Experiments with high explosives.

The fortification bill approved July 5, 1884, provides that a sum not exceeding fifteen thousand dollars "may be used for the expenses of experiments in the use of dynamite or other high explosive projectiles," and the Department has given all proper assistance and encouragement to private parties having designs or inventions that promised success. The trials thus far have been tentative merely, and nothing has been developed that calls for any detailed mention.

Experiments have been made during the year by the Ordnance Board in firing shells charged with explosive gelatine from service guns. The practicability of making such firings, using ordinary gunpowder as the propelling agent, with safety and certainty seems now almost assured. Some 8-inch steel shell have been ordered with a view to increasing the penetration in iron plates, and with the expectation that the explosive effect of the gelatine will thereby be considerably augmented.

STEEL GUNS AND CARRIAGES FOR FIELD SERVICE.

The steel 3.2-inch breech-loading gun designed by the Ordnance Board is now under trial by the Board for Testing Rifled Guns, &c. The gun is made from open-hearth steel, supplied by the Midvale Steel Company, and consists mainly of a steel tube, forged and annealed, a steel jacket, forged and oil tempered, a trunnion hoop, which is an oil-tempered steel casting, and a sleeve and a key ring of forged and oil-tempered steel. The length of bore is 26 calibers, the weight 793 pounds, and the rifling consists of 24 grooves, having a uniform twist of one turn in thirty calibers. The gun was manufactured at the Watertown Arsenal (see Appendix 33), under the supervision of Major Parker.

The experimental character of this gun necessitated a number of changes in details during its manufacture; but as the work was being done at a Government shop no material expense was thereby incurred. Indeed, the changes made, which were veritable improvements on the original design, were suggestions mainly from the Officers of the Department entrusted with the manufacture. Mention is here made of these facts as showing, from the satisfactory character of the result, the wisdom of prosecuting purely experimental work at some Government establishment.

Prior to being turned over to the Board for Testing Rifled Guns, &c., the gun was fired some sixty rounds under the direction of the Ordnance Board. (See Appenpix 14.)

The results obtained with 3½ pounds of powder and a 13-pound projectile are thus summarized:

Initial velocity.	Pressure.	Energy.				
		Total.	Square inch of cross section.	Per pound of powder.	Per pound—weight of piece.	Per cent. realized.
Feet.	*Pounds per sq. inch.*	*Foot-tons.*	*Foot-tons.*	*Foot tons.*	*Foot-pounds.*	
1635 Mean of 18 rounds...	29116 Mean of 25 rounds	241. 20	29. 99	68. 91	681. 53	78

Accuracy of fire at a target 20 by 40 feet at 1 mile distance:

Mean vertical deviation	3. 63 feet.
Mean horizontal deviation	3. 23 feet.
Mean deviation	4. 26 feet.

Pressure and velocity with 3.5-pound charges and 13-pound projectile:

Number of rounds.	Velocity 100′ from muzzle.	Pressure per square inch.	Remarks.
Mean of 6 rounds	1605	27, 375	Using Freyre gas check.
Mean of 6 rounds	1629	29, 950	Using De Bange gas check.

These results are deemed extremely favorable as compared with the firing of similar guns in European services. (See Appendix 14.)

The gun has been fired in all, thus far, two hundred and forty-four rounds, and without any apparent injury or deterioration whatever. The results of the firings are embodied in the progress report of the Board for Testing Rifled Guns, &c. (See Appendix 22.)

As is usual with experimental work, doubtless the *trials* will indicate some slight modifications still to be made in the definite model of the gun.

The new steel field carriage now being used in the trial of the 3.2-inch breech-loading gun was manufactured by Lieutenant Colonel Mordecai at the Watervliet Arsenal. (For description, see Appendix 34.) It has developed some points of weakness during the firings, but of a nature such as to admit of remedy in future constructions.

As it is but rational to anticipate the success of this field gun and its carriage, an estimate has been submitted and an appropriation is asked for to enable the Department to continue their fabrication to arm the light batteries of our Army with a modern breech-loading field gun and carriage.

During the past year a copper-banded projectile has been tested with the 3.2-inch field gun and has given excellent results, and other banded projectiles of larger caliber are under fabrication for experiment; a suitable shell and shrapnel for the field service have also been devised and tested, and point time and percussion fuses have been adopted; experiments with base percussion fuses are still in progress.

These various trials have been conducted under the able supervision of the Ordnance Board, consisting of Col. T. G. Baylor, Maj. G. W. McKee and Capt. Chas. Shaler, who have in most instances prepared the designs to be tested. This Board has thus done most excellent work in establishing standards for construction and supply of suitable ammunition for field and sea-coast service, in designing a field steel gun which has already given fair promise of ultimate success, and, in connection with Maj. F. H. Parker, commanding the Watertown Arsenal, in remodeling our existing outfit of wrought-iron sea-coast carriages to adapt them to the larger charges now employed or to the introduction of the converted rifled guns.

Full records of the very accurate tests of the material procured by the Department for gun construction will be published in the forthcoming report on the Tests of metal made at the Watertown Arsenal during 1884.

Reference has been already made to the reports by officers of the Department, which directly pertain to the duties of this office, and to the manufacture of cannon, and I invite special attention to those of unusual interest and value made by—

Captain Lyle, on the construction of the 6.5-inch Mann breech-loading gun. (Appendix 25.)

Lieutenant Birnie, on fabrication of coiled wrought-iron tubes for 8-inch rifle conversions, and of life-saving mortars. (Appendices 27 and 28.)

Lieutenant Borup, on construction of the 8-inch converted rifle, steel lined. (Appendix 26.)

Lieutenant Bruff, on construction of the 3.2-inch steel breech-loading field gun. (Appendix 33.)

Lieutenant Medcalfe, on manufacture of billets for steel wire, at the Otis & Co.'s works. (Appendix 30.)

Lieutenant Hobbs, on manufacture of steel hoops, steel tubes, &c., at the Midvale Steel Works. (Appendix 29.)

I have thus given, in brief, an idea of the labors of this Department, during the year, in the line of gun construction. The exhibit is an encouraging one, and evidences excellent results of the intelligent study and experience in practical details of the officers entrusted with this most important branch of the ordnance service. There is no reason to doubt their ability to grapple with success the most difficult theoretical and practical problems of heavy gun construction. Should Congress, after full investigation and consideration, determine on appropriations liberal enough to encourage the manufacture of gun steel and to procure the plant for gun factories, for the proper and speedy armament of our coast defenses, the country can rest secure in the belief that this Department, through the labors of its officers, will attain the same prominence in this regard that it held twenty five years ago.

In this connection, I take great pleasure in highly commending Capt. C. S. Smith, in charge of the construction division of this office, for distinguished merit and most thorough and efficient services.

THE MILITIA.

So much has been already written and recommended in previous reports on the great importance of encouraging the formation of volunteer organizations throughout the country, by a large increase of the annual appropriation for arming and equipping the militia, and the passage of the bill in the Senate and the action of the House pointing to a favorable result, any further discussion of the matter seems unnecessary.

It is interesting, however, to note the opinion of General Washington, in a circular letter to the governors of the several States, from his headquarters, Newburg, June 18, 1783. He says:

> "As there can be little doubt but Congress will recommend a proper peace establishment for the United States, in which a due attention will be paid to the importance of placing the militia of the Union upon a regular and respectable footing, if this should be the case, I should beg leave to urge the great advantage of it in the strongest terms.
>
> "The militia of this country must be considered as the palladium of our security and the first effectual resort in case of hostility; it is essential, therefore, that the same system should pervade the whole; that the formation and discipline of the militia of the continent should be absolutely uniform; and that the same species of arms, accouterments, and military apparatus should be introduced in every part of the United States. No one, who has not learned it from experience, can conceive the difficulty, expense, and confusion which result from a contrary system, or the vague arrangements which have hitherto prevailed."

That the Senate bill now pending in the House may become a law, is recommended in the strongest terms.

UNITED STATES TESTING MACHINE.

Maj. F. H. Parker, commanding the Watertown Arsenal has made his report of tests of iron, steel, and other materials for industrial purposes for the past fiscal year. The report will be submitted to you for transmission to Congress at the opening of the next session, as required by law.

The number of public tests made during the year was 1,424, and in addition 411 tests for private parties were made, making a total of 1,835 tests. More than three-fourths of the tests made were for Government service, and unless an additional machine is provided, as estimated for, all private tests will have ere long to be discontinued. The fact that during the year the machine was disabled and undergoing repairs for a period of forty-one days, is the strongest argument in favor of additional facilities for the prosecution of such important work.

I have the honor to submit the following papers, heretofore referred to:

Appendix 1. Statement of principal articles procured by fabrication during the year ended June 30, 1884.

Appendix 2. Statement of principal articles procured by purchase during the year ended June 30, 1884.

Appendix 3. Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1884.

Appendix 4. Apportionment for the fiscal year ended June 30, 1884, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667, Revised Statutes.

Appendix 5. Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1883, to June 30, 1884, under section 1667, Revised Statutes.

Appendix 6. Statement of arms, ammunition, &c., distributed to the Territories and States bordering thereon from July 1, 1883, to June 30, 1884, under the joint resolutions of July 3, 1876, March 3, 1877, and June 7, 1878, and the act of May 16, 1878.

Appendix 7. Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1883, to June 30, 1884, under section 1225, Revised Statutes.

Appendix 8. Report of action taken during the year ended June 30, 1884, under the provisions of the act approved March 3, 1881.

Appendix 9. The oxidation of metallic parts of the Springfield rifle.

Appendix 10. Report of the principal operations at the Rock Island Arsenal, Illinois, during the fiscal year ended June 30, 1884. (2 plates.)

Appendix 11. Report of the principal operations at the United States Powder Depot, Dover, N. J., during the fiscal year ended June 30, 1884. (3 plates.)

Appendix 12. Description of the rod bayonet and attachment, and front and rear sight for the Springfield rifle, model 1884. (1 plate.)

Appendix 13. Report of artillery practice at the Narrows, New York Harbor. (3 plates.)

REPORTS OF THE ORDNANCE BOARD.

Appendix 14. Partial trial of 3.2-inch breech-loading steel rifle. (4 plates.)

Appendix 15.—Report on solid-band shell for 3.2-inch breech-loading steel gun. (7 plates.)

Appendix 16.—Report on shrapnel and shell for 3.2-inch breech-loading steel gun. (2 plates.)

Appendix 17.—Trial of 10-inch rifled mortars Nos. 1 and 2. (8 plates.)

Appendix 18.—Trial of the improved Gardner gun, caliber .45. (13 plates.)

Appendix 19.—Progress report on explosive gelatine. (2 plates.)

Appendix 20.—Report on the Lyman-Haskell multicharge gun.

REPORTS OF THE BOARD FOR TESTING RIFLED CANNON APPOINTED UNDER THE ACT OF JULY 5, 1884.

Appendix 21.—Trial of an 8-inch muzzle-loading rifle, lined with a steel tube—converted from a 10-inch smooth-bore Rodman gun.

Appendix 22.—Trial of 3.2-inch breech-loading steel rifle. (1 plate.)

Appendix 23.—Trial of H. F. Mann's 6½-inch breech-loading rifled cannon. (5 plates.)

ORDNANCE CONSTRUCTION.

Appendix 24.—Table of the Hotchkiss single-barrel rapid firing non-recoil guns.

Appendix 25.—Construction report of the 6½-inch Mann breech-loading rifle. (1 plate.)

Appendix 26.—Construction report of an 8-inch rifle converted from a 10-inch smooth-bore Rodman gun by lining with a steel tube. (1 plate.)

Appendix 27.—Report on the manufacture of coiled wrought-iron tubes and the conversion of 10-inch smooth-bore Rodman guns into 8-inch rifles. (7 plates.)

Appendix 28.—Report on the manufacture of life-saving guns and projectiles. (5 plates.)

Appendix 29.—Report on the manufacture of the Midvale steel forgings for gun construction.

Appendix 30.—Report on the manufacture of billets and bars and a steel casting for gun construction at the Otis Steel Works. (1 plate.)

Appendix 31.—Report on physical properties of materials for gun construction at the South Boston Iron Works.

Appendix 32.—Report on the manufacture of projectiles and sabots. (6 plates.)

Appendix 33.—Report of manufacture of 3.2-inch breech-loading steel rifle at Watertown Arsenal. (14 plates.)

Appendix 34.—Report on construction of metallic field carriages for 3.2-inch breech-loading rifles. (3 plates.)

Appendix 35.—Description of the Piper field and siege gin. (5 plates.)

Appendix 36.—Tests of Whitworth steel for 8-inch breech-loading rifle and 12-inch rifled mortar.

Appendix 37.—The barbette carriage for 15-inch smooth-bore gun and 11-inch rifle. (2 plates.)

Appendix 38.—Proposed 10-inch steel breech-loading rifle. (1 plate.)

Appendix 39.—Showing the stations and duties of the officers of the Ordnance Department.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

To the Hon. SECRETARY OF WAR.

APPENDIX 1.

***Statement of principal articles procured by fabrication during the fiscal year ended June* 30, 1884.**

CLASS I.

1	3.2-inch breech-loading rifled steel gun.

CLASS II.

100	gun carriages for life-saving service.
7	metallic carriages for 3.20-inch rifle.
2	metallic limbers for 3.20-inch rifle.
1	carriage and chassis for 11-inch rifle.
1	carriage and chassis for 15-inch gun.

CLASS III.

1	breech-sight for 12-pounder mountain howitzer.
3	breech-sights for 3-inch rifle.
100	combination levels.
102	chocks.
8	fuse-plug wrenches.
100	gunners' haversacks.
7	gun covers.
14	gunners' sleeves.
61	handspikes.
18	sets artillery harness for 2-wheel horses.
10	sets harness for Laidley cavalry forge.
170	harness sacks.
118	lanyards.
9	muzzle or front sights.
200	powder measures.
132	priming wires.
5	pouches for sights.
100	quoins.
50	securing stakes.
17	scrapers for cannon.
16	shot carriers.
12	sponge covers for 3-inch rifle.
13	sponge covers for 3.2-inch rifle.
20	sponge covers for 12-pounder gun.
2	sponge covers for 6-pounder gun.
100	sponge covers for 2½-inch life saving guns.
20	sponge covers for 12-pounder mountain howitzer.
100	sponges and rammers for 2½-inch life-saving guns.
14	sponges and rammers for 3.20-inch rifle.

2	sponges and rammers for 8-inch siege howitzer.
1	sponge and rammer for 6-pounder gun.
70	sponges and rammers for 12-pounder mountain howitzer.
90	sponges and rammers for 3-inch rifle.
6	sponges and staves for 10-inch Rodman gun.
26	sponges and staves for 3-inch rifle.
2	sponges and staves for 3.2-inch rifle.
21	sponges and staves for 12-pounder gun.
4	sponges and staves for 4.5-inch rifle.
1	sponge and stave for 20-inch gun.
46	vent covers.
18	vent pieces.
20	wipers for mortars.
1	pocket wiping apparatus for multicharge gun.
100	wiping rods and wipers.

CLASS IV.

85	3.2-inch shell.
25	3.2-inch shrapnel.
123	4.2-inch Eureka shot.

CLASS V.

17	8-inch service canister.
5	8-inch wire canister.
25	12-pounder shell, strapped.

CLASS VI.

34,380	Springfield rifles, caliber .45.
753	Chaffee-Reece magazine rifles, caliber .45
250	officer's swords.
1	cavalry saber.

CLASS VII.

ARTILLERY ACCOUTERMENTS.

2,700	saber belts.
200	saber-belt plates.

CAVALRY ACCOUTERMENTS.

6,102	carbine slings.
2,676	saber belts.
102	saber slings.
1,000	saber snaps.
69	Stuart's attachments.
1,404	pistol holsters.
975	revolver belts.

INFANTRY EQUIPMENTS.

9,810	bayonet scabbards.
1,733	bayonet-scabbard bodies.
5,010	blanket bags.

5,010	blanket-bag shoulder straps.
5,986	pair coat straps.
1,828	clothing-bag straps.
6,200	canteens.
6,801	canteen straps.
1,000	canteen covers.
50	canteen corks and chains.
4,551	cartridge boxes, pattern 1874, McKeever.
8,710	cartridge-belt plates.
2	cartridge belts.
12	frogs, sliding.
3,896	gun slings.
4,764	haversacks.
1,500	haversack straps.
4,655	hunting-knife scabbards.
7,300	meat cans.
6,000	tin cups.
6,911	waist belts.
3,093	waist-belt plates.
1,700	waist belts and plates, pattern 1874.
2	waist belts, non-commissioned officers.

APPENDAGES.

400	brush-wipers for shells.
141	bullet molds, 4 balls, caliber .45.
250	cleaning rods for shot-guns.
12,604	headless shell extractors.
15,319	screw-drivers.
28,291	wooden wiping-rods.
500	pine plugs for rifle-muzzle.
1	spirit-level.

HORSE EQUIPMENTS.

2,171	bridles, curb, cavalry.
7,008	bits, curb, cavalry.
1,000	bridles, watering.
119	carbine sockets.
1	carbine holster.
3,001	cinchas, or hair girths.
808	cincha straps.
238	girth safes.
3	curry combs.
1,240	halters and straps.
1,918	halter straps.
261	halter headstalls.
3	headstalls for bridles.
48	halter bolts.
60	halter squares.
6,000	fasteners for side lines.
100	foot staples, brass.
200	brass staples for saddle bags.
9,150	horse brushes.
1,000	horse covers, with surcingles.
40	loops.

8,791	nose bags.
312	ovals, guard plate.
3,980	picket pins.
1	rifle boot.
2,003	saddles, cavalry, leather-covered.
82	saddle cloths, hair.
22	saddle bags, leather.
24	saddle bag studs.
8,376	side lines.
1,096	spur straps.
430	stirrup straps.
1	wooden stirrup.
1,326	staples for rings.
600	rings, D.

CLASS VIII.

15,477	blank cartridges, 3-inch gun.
8,579	blank cartridges, 6-pounder gun.
4,589	blank cartridges, ½ pound.
1,230	blank cartridges, 1 pound.
500	blank cartridges, 2 pound.
4,300	blank cartridges, 12-pounder mountain howitzer.
13,178	blank cartridges, light, 12-pounder gun.
800	blank cartridges, heavy, 12-pounder gun.
7,417,135	rifle-ball cartridges, caliber .45, reloading.
583,795	rifle and carbine blank cartridges, caliber .45, reloading.
40,760	rifle-ball cartridges, caliber .45, 2.4-inch shell, reloading, 80 grains powder.
1,019,149	carbine ball cartridges, caliber .45, reloading.
508,218	revolver ball cartridges, caliber .45, reloading.
257,016	revolver blank cartridges, caliber .45, reloading.
5,068,000	rifle bullets, caliber .45, 500 grains.
899,538	carbine bullets, caliber .45, 405 grains.
122,000	revolver bullets, caliber .45.
2,112,700	round balls, caliber .45.
5,380	electric primers for cannon.
514	metallic-fuse plugs, time.
51	wooden fuses.

CLASS IX.

1	capstan.
10	capstan bars.
2	aiming stands.
12	chocks, gin.
6	disks.
1	gin, field, and siege, Piper pattern.
144	guards for fencing swords.
2	hand carts.
1	portable harness rack.
6	platforms for mortars.
7	platforms for siege carriages.
8,552,000	pasters.
5	rollers, long.
5	shifting planks.
6	skids.

234	shot marks.
184	signal flags.
71	streamers for rifle range.
3	targets, Brinton.
17	targets, Cushing.
379	targets, Laidley revolving.
6	truck targets.
29, 550	paper targets.
1, 002	target frames.
362	parts of targets.
830	parts of Laidley revolving targets.

RELOADING TOOLS.

66	boxes reloading tools.
1	set hand-reloading tools.
152	bullet-mold gates.
65	blocks, priming, lead.
100	caps, crimping die.
124	chargers.
255	combination anvils.
64	funnels.
178	bottoms, reloading tool boxes.
10	primer extractors.
170	priming tools.
11	priming tool spindles.
849	pins for primer extractor.
257	reloading dies.
226	reloading punches.
224	resizing dies.
100	resizing punches.
50	resizing die sockets.
62	shell scrapers.
2	screws, primer extractors.
1	key and washer for Michaelis' powder charger
103	washers for reloading punch.

CLASS X.

13	ammunition chests.
1	axle body for field carriage.
1	bed-plate for Gatling-gun carriage.
1	bolster for 4.5-inch siege carriage.
1	linch-pin and washer, Laidley cavalry forge.
2	pair shafts for Laidley cavalry forge.
10	poles, field or siege carriage.
2	thills for Hotchkiss mountain carriage.
6	rear huster bolts for 15-inch chassis.
8	carriage hooks for 15-inch chassis.
4	singletrees for caisson of 3.20-inch rifle.
2	splinter bars for caisson of 3.20-inch rifle.
2	straps for field caisson.
2	middle rails for field caisson.
6	stay pinkeys for field caisson.
16	traces for splinter bars.
1	wheel, No. 1, complete.

1	wheel, No. 5, complete.
1	wheel, Archibald patent.
1	wheel, Sarvin patent.
10	shoes for No. 1 wheel.
18	collars.
2	saddles.
41	valise straps.
12	seats for driver's saddle.
7	iron props for sponges and rammers.
2	handspike rings.
50	rammer heads, 3-inch gun.
10	rammer heads, 6-pounder gun.
24	rings for rammer heads.
50	sponge heads, 3-inch rifle gun.
10	sponge heads, 6-pounder gun.
32	sponges, 12-pounder mountain howitzer.
4	sponges, 13-inch sea-coast mortar, woolen.
200	wood sabots for 15-inch gun.
50	sabots for multicharge gun.
75	sabot coppers for multicharge gun.
250	sabot leathers for multicharge gun.
200	tin straps for wood sabots, 15-inch gun.

SPARE PARTS OF SPRINGFIELD RIFLE AND CARBINE, VIZ:

1,982	stocks (wood part) Springfield rifle.
81	tips.
118	tip screws.
324	ramrod stops.
56	band springs.
70	side screw washers.
95	butt plates.
356	butt plate screws.
26	guard plates.
75	guard bows.
173	guard bow swivels.
257	guard-bow swivel screws.
32	guards, complete.
269	guard-bow nuts.
1,249	triggers.
700	trigger screws.
638	guard screws.
890	rear-sight bases.
796	rear-sight base springs.
1,358	rear-sight base screws.
1,603	rear-sight leaves.
1,097	rear-sight slide plates.
994	rear-sight slide blocks.
800	rear-sight slide springs.
7,520	rear-sight slide screws.
780	rear-sight centering pins.
837	rear-sight joint pins.
5,724	rear-sight buckhorn plates.
196	rear-sights, complete.
86	barrels.
3,128	rear sight covers.

3, 421	extractors.
86	hinge pins.
1, 508	ejector springs.
5, 283	ejector-spring spindles.
95	ejector studs.
184	cam latches.
406	breech-block caps.
134	thumb pieces.
19	breech blocks.
3, 259	breech-block cap screws.
6, 982	firing pins.
3, 096	firing-pin screws.
846	cam-latch springs.
42	breech screws.
859	front sights.
329	front-sight rivets.
1, 067	tang screws.
20	carbine bands.
10	band-swivel hooks.
27	bands, upper.
10	band-swivel pins.
48	bands, lower.
111	lock plates.
1, 675	main springs.
56	main-spring swivels.
24	main-spring swivel rivets.
23	hammers.
1, 629	tumblers.
3, 549	tumbler screws.
2, 589	bridles.
306	bridle screws.
1, 780	sears.
2, 629	sear screws.
1, 440	sear springs.
874	sear-spring screws.
918	side screws.
272	ramrods.
3	ramrods, jointed.
495	bayonets.
50	bayonet clasps.
445	bayonet-clasp screws.
135	bayonets, complete.
195	locks, complete.
624	stocks.
1, 136	pistol grips.
508	pistol-grip screws.
51	barrel studs.
10	rod bayonets.
35	rod-bayonet springs.
12	firing-pin springs.
1	stock for officer's rifle.
1	ramrod head “
1	ramrod tip “
2	thimbles “
7, 300	cartridge bags, ½ pound.
500	cartridge bags, 1 pound.

3, 000	cartridge bags, 2 pounds.
9, 000	cartridge bags, 3-inch gun.
4, 610	cartridge bags, 6-pounder gun.
70	cartridge bags, 4½-inch siege gun.
3, 132	cartridge bags, 8-inch converted rifle.
900	cartridge bags, 10-inch Rodman gun.
12, 000	cartridge bags, light 12-pounder gun.
150	cartridge bags, 3.2-inch breech-loading chambered rifle.
2, 000	cartridge bags, 12-pounder mountain howitzer.
4, 025, 000	cartridge primers.
4, 110	rifle-cartridge shells.
63, 000	revolver cartridge shells.
14, 891	shot-gun cartridge shells.

MISCELLANEOUS.

1, 567	arm chests.
4, 199	boxes, packing.
1	box, packing, tin.
200	powder barrels.
448	cans, tin.
2	book cases.
1	mail pouch.
21	tree guards.
50	boxes cleaning material.
50	boxes of ingredients for leather blacking.
5	pounds of ingredients for leather blacking.
114	portable arm racks.
2	book-racks.
200	boxes stencil blacking.
2	stands for polishing wheels.
40	ounces scouring material.
173	quarts blacking for leather.
1½	pints browning mixture.
2	arbors.
590	brushes, assorted.
16	bitts, assorted.
2	calipers.
154	chisels, various.
13	clamps, saddlers'.
500	disks, pressure, copper.
1, 974	dies, various.
1, 264	drills.
11, 100	copper cylinders.
2	dippers, tin.
1, 379	files, assorted.
1	furnace, plumbers'.
1	furnace, annealing.
60	gauges.
600	gas-checks.
9	hammers.
22	horses, saddlers'.
12	mallets.
1, 129	mills, armorers'.
125	mandrels.
1	polishing frame.
676	punches, assorted.

309	reamers.
3	scrapers.
2	sets stamps and figures.
6	pulleys.
13	seal stamps.
1	set stencil outfit.
160	taps, various.
1	indenting tool.
1, 358	tools for current service.
1	set tools, pressure gauge.
1	set sabot tools.
11	wrenches.
1	wax-heating apparatus.
1	glue-pot.
2	smiths' apron.
10, 000	brass bar-buckles, $\frac{5}{8}$ inch.
5, 000	brass bar-buckles, $\frac{3}{4}$ inch.
5, 000	brass bar-buckles, $\frac{7}{8}$ inch.
902	brass rings, $1\frac{1}{4}$ inch.
148	brass-rings, $2\frac{1}{2}$ inch.
22	cast-iron posts.
1	plate sheet iron.
237	stoves for Quartermaster's Department.
870	parts of stoves for Quartermaster's Department.
24	spiral springs.
6	springs, crusher gauge.
4	test specimen-heads.
3	ring-gauges for setting star-gauge.
2	ring-gauges for projectiles.
2	star gauges, complete.
2	sets star-gauge measuring points.
1	rifle-guide for star-gauge points.
300	pressure gauge-blocks.
170	pounds wheel grease.
55	gallons lacker.
4, 809	pounds harness oil.
64	ounces polish for leather.
537	pounds black paint.
2, 140	pounds olive paint.
2, 211	pounds paint, assorted.
50	pounds black wax.

MACHINES.

1	machine, dynamo-electric.
1	machine, loading friction primers.
2	machines, foiling friction primers.
1	machine, making hair-rope.
1	machine, primer charging.
1	machine, primer varnishing.
1	machine, cartridge heading.
3	machines, head trimming.
1	machine, cartridge tapering.
2	machines, pocket sizing.
2	machines, pocket venting.
2	primer presses.

APPENDIX 2.

Statement of principal articles procured by purchase during the year ended June 30, 1884.

CLASS I.

51	8-inch muzzle-loading rifles converted from 10-inch smoothbore guns.
135	2½-inch bronze life-saving guns.
1	Hotchkiss revolving cannon, 53$^{\text{mm}}$.
1	Hotchkiss 1-barrel shoulder gun, 47$^{\text{mm}}$.
1	Lowell battery gun, caliber, .45.
25	Gatling guns (10 barrels) caliber, .45.

CLASS II.

1	carriage for Hotchkiss revolving cannon, 53$^{\text{mm}}$.
1	carriage for Lowell battery gun.

CLASS III.

2	baskets for mortar implements.
100	feed magazines, Gatling gun, caliber, .45.
6	gun scrapers.
200	paulins, 12 by 15 feet.
2	sets reloading tools, Hotchkiss gun.
4	sights.
5	seats.

CLASS IV.

74	10-inch mortar shells.
1,539	8-inch Eureka shot.
25	8-inch Parrott-cored shot.
9	8-inch experimental shell for explosive gelatine.
200	15-inch solid shot.
250	6.5-inch Mann's solid shot.
150	6-inch shot for multicharge gun.
600	4½-inch Butler shot
500	4½-inch Butler shell.
500	3-inch Butler-cored shot.
500	3-inch Butler shell.
25	3.20-inch Hotchkiss case shot.
25	3.20-inch Hotchkiss shell.
1,620	2½-inch projectiles for life-saving gun.
1,000	shell for Hotchkiss shoulder gun, 47$^{\text{mm}}$.
2,000	shell for Hotchkiss revolving cannon, 53$^{\text{mm}}$.

CLASS VI.

200	Hotchkiss magazine rifles, caliber .45.
24	breech-loading shot-guns.
2,002	Colt's revolvers, caliber .45

CLASS VII.

3,052	saddle blankets, cavalry.
500	cavalry saber belts and plates.
5,950	cartridge boxes.
2	curry combs.
2	cincha straps.
1,728	escutcheon pins.
138	pound escutcheon pins for saddles.
2	horse brushes.
2	horse covers.
3	lariats.
300	sets knives and forks.
1	saddle-bag (California pattern).
1	saddle.
2,500	steel bayonet scabbards.
6,075	waist belts and plates.
1,000	woven loops for cartridge boxes.

CLASS VIII.

6,550	pounds blasting powder.
20,000	pounds cannon powder.
124	pounds giant powder.
4,000	pounds granulated powder.
49,000	pounds hexagonal powder.
106,825	pounds musket powder.
182,500	rifle ball-cartridges, caliber .45.
150,000	rifle blank cartridges, caliber .50.
10,000	rifle blank cartridges, caliber .45.
28,800	brass shells.
900	giant-powder caps.
239,000	lead bullets.
10,000	lubricants.
10	pounds nitro-glycerine.
183,000	primers for cartridges.
9,245	paper shells.
187	paper cylinders.
18,800	pounds drop shot.
80	reloaders.
17	sets reloading and cleaning tools for shot gun.
2,124	feet safety-fuse.
746,000	wads.

CLASS IX.

11	double blocks.
13	single blocks.
3	treble blocks.
14	pulley blocks.

5, 100	marksman's buttons.
2	hydraulic jacks.
10	rollers.
1	sheave.
2	sling carts.
2	range-finders, Pratt's.

CLASS X.

70	halter chains.
2, 000	halter bolts.
5, 500	halter squares.
17, 120	roller buckles.
6, 294	rings.
100	stocks for Hotchkiss magazine guns.
666	8-inch Butler sabots.
5	saddle-trees.
4, 452	spring-snaps.
16	wheels, artillery.

PART SECOND: CLOTH, ROPE, THREAD, &C.

227	yards burlaps.
175	yards canvas.
$114\frac{1}{12}$	yards carpeting.
1, 721	pounds cord and twine.
1, $590\frac{2}{3}$	yards cord and twine.
$69\frac{1}{8}$	yards oil-cloth.
$8\frac{3}{4}$	yards enameled cloth.
$894\frac{3}{4}$	square yards cotton cloth.
28, $414\frac{1}{2}$	yards cotton cloth.
7, $534\frac{1}{2}$	pounds cotton waste.
$288\frac{3}{4}$	yards cotton felt.
110	yards hair felt.
$372\frac{1}{8}$	yards flannel.
100	yards canton flannel.
1, 301	pounds hair.
50	pounds hemp packing.
10	yards linen cloth.
$131\frac{4}{15}$	yards matting.
$376\frac{1}{4}$	pounds marlin.
$16\frac{1}{2}$	yards velvet.
50	pounds oakum.
7, 697	pounds rope.
60	feet rope.
$16\frac{1}{3}$	pounds silk.
1, $812\frac{1}{3}$	pounds thread.
$50\frac{1}{2}$	yards ticking.
24	towels.
46	yards toweling.
100	pounds tow.
11, $551\frac{1}{4}$	yards webbing.
$13\frac{1}{2}$	yards woolen cloth.
4, 026	pounds wool.
73	pounds yarn.

FORAGE.

19, 286	pounds barley.
29, 504	pounds bran.
798$\frac{33}{56}$	bushels corn.
25½	barrels flour.
11¾	bushels grass-seed.
13, 435	pounds ground-feed.
57, 367	pounds hay.
790	bushels meal.
10, 246	bushels oats.
37	barrels salt.
63, 712	pounds straw.

IRONMONGERY.

101½	pounds babbitt metal.
548, 612	pounds I and channel beams.
4	boilers.
362	feet boiler tubes.
1, 836	pounds bolts.
9, 848	bolts and staples.
2, 716¾	pounds sheet brass.
509	buckles.
329	buttons.
625½	pounds rivets and burrs.
4, 681½	pounds brass castings.
117, 226	pounds iron castings.
11, 611⅞	pounds bar copper.
413, 439	pounds sheet copper.
3, 302	pounds chain.
28, 253	eyelets and hooks.
412	gas fixtures.
270	gas burners.
336½	feet gas pipe.
96½	pennyweights gold.
245	hasps and hooks.
1, 376	pairs hinges.
84	hose fittings.
44, 821	horse-shoes.
3, 689	pounds horse-shoe nails.
2	hydrants.
517, 759½	pounds wrought iron.
3, 997½	pounds hoop iron.
26, 564	pounds sheet iron.
150$\frac{32}{100}$	tons pig-iron.
754	knobs, assorted.
7, 996¾	pounds lead.
6, 033	pounds lead pipe.
1	set lightning rods.
110	feet lightning rods.
774	locks, assorted.
70, 706	pounds nails.
22, 212	saddle nails.
3, 845	pounds nuts and washers
150	pulleys.
1	pump.

19, 781	feet iron pipe.
3, 799	pipe fittings.
3, 591	pounds rivets.
2, 877	feet metallic rope.
874	pounds weights and pulleys.
199¾	feet shafting.
2 5/16	pounds silver.
103	pounds german silver.
506⅞	pounds solder.
11	pounds spelter.
713, 941	pounds steel.
74	springs.
336	staples.
333	pounds copper tacks.
4, 099, 000	tacks.
29, 804	pounds block tin.
66½	boxes sheet tin.
1, 262	pounds tin-foil.
300¾	pounds tubing.
23	feet tubing.
208	window fixtures.
25, 804	pounds wire.
3, 518⅚	square feet wire cloth.
211½	square feet wire netting.
2, 174¼	pounds zinc.
3, 090½	gross screws.
4, 542¼	pounds sheet steel.
207	feet iron railing.
154	hangers or bearings.
46	steel plates.

LEATHER.

84, 423¼	feet collar leather.
2, 392¼	feet bellows leather.
57	feet enameled leather.
50, 527½	pounds harness leather.
184	pounds buff leather.
113⅝	pounds lace leather.
476¾	pounds sole leather.
36	pounds walrus leather.
560	sides harness leather.
923	sides collar leather.
1, 776	sides bridle leather.
28	sides lace leather.
187	sides bellows leather.
20	sides alum-tanned leather.
20	sides oak-tanned leather.
13, 914	feet belting leather.
1, 900	feet belt lacing.
158¾	pounds belt lacing.
16	leather belts.
435½	feet rubber belting.
15	sheep skins.
2, 498⅞	pounds bristles.

LUMBER.

3,472	feet battens.
1,158,964	feet boards.
6,374	feet joists.
49,658	laths.
757,579	feet plank.
115,850	feet scantling.
118,065	shingles.
152,762	feet timber.
28,358	feet pine strips.
9,276	feet moulding.

BUILDING MATERIAL.

431¼	pounds asbestos.
32	asbestos rings.
1,815,630	bricks.
3,006¾	barrels cement.
106	barrels clay.
46	doors, wood.
327½	feet drain-pipe.
643	feet drain-tiles.
126¾	cubic yards gravel.
9,156	pounds kaolin.
2,851	barrels lime.
16	barrels plaster of Paris.
2,829	cubic yards sand.
427	pounds hair.
3,331$\frac{25}{100}$	cubic yards stone.
6,183	square feet stone.
89	caps, steps, and sills.
1,343⅔	yards terra-cotta pipe.
10,225	feet weather strips.
69	pairs window blinds.
47	window frames.
187	window sash.

MATERIALS FOR HEATING, LIGHTING, ETC.

12	bath tubs.
1,230	brooms.
337	brushes.
211	pounds candles.
221⅜	square feet card clothing.
358	chamois skins.
8	chandeliers.
7,271	barrels charcoal.
2,641$\frac{1013}{2240}$	tons anthracite coal.
3,609$\frac{1025}{2240}$	tons bituminous coal.
177,993	pounds coke.
351	pounds corundum flour.
168	corundum and emery wheels.
10	carats diamond powder.
62½	reams crocus and emery cloth.
3,249½	pounds emery.
24	grates.

5	lamps.
300	lamp fixtures.
76	lanterns.
80	lantern fixtures.
41½	gross matches.
10	boxes mineral wool.
13	pitchers, jugs, &c.
12	tubs, &c., for laundry.
12	registers.
58	pounds rosin.
602½	pounds rotten stone.
65¾	reams sand paper.
8,167¾	pounds soap.
636	gallons soft soap.
313¼	pounds sponge.
23	stoves, heating, &c.
330	feet steam-pipe covering.
378	papers tripoli.
6,706	fire-brick.
521½	cords fire-wood.
4	hot-air furnaces.

MATERIALS FOR OFFICE USE.

150	gross rubber bands.
202¾	pounds sealing-wax.
10,000	seals.
37	rubber stamps.
1	office table.
1¾	gross thumb-tacks.
333	yards tracing cloth.
6	clocks.
3	water coolers.
250	sheets bristol boards.
1	caligraph.
288	pencil-point protectors.
1,500	cards, assorted.
13	chairs.
2	desks.
9,400	dials for watch clock.
45	drawing instruments.
1	box drawing instruments.
72,403	envelopes.
2	hektographs.
3,723	lead pencils.
116½	gross pens.
47	drawing pens.
29	pounds pins.
150	pieces india rubber.
293	bottles ink.
425	pounds printer's ink.
3	letter presses.
50	bottles mucilage.
363½	reams paper.

LABORATORY STORES.

2	hydrometers.
145	insulators and brackets.
118	jars.
2	lenses.
2	slate and marble slabs.
561	parts of electric batteries.
700	feet of material for electric batteries.
3	barometers and thermometers.
33, 163⅓	pounds acid, various.
750	gallons alcohol.
57	pounds alum.
100	pounds ammoniated copper.
106½	pints aqua ammonia.
149, 864	pounds bone.
241	pounds borax.
79	pounds camphor.
10	pounds carbonate of iron.
5	pounds chloride calcium.
8	ounces citrate of iron and ammonia.
125	pounds sulphate of copper.
565	pounds electropian fluid.
90	grains chloride of gold.
108	pounds gum arabic.
10	pounds gum tragacanth.
5, 950	pounds dynamite.
1	galvanometer.
3	electric batteries.
142½	gallons isinglass.
16¼	gallons molasses.
117½	reams paper.
30, 356¾	pounds paper.
20	pounds pepper.
5	barrels pitch.
79, 250	pounds straw boards.
2, 497	pounds tallow.
1, 072	pounds sulphur.
105½	pounds beeswax.
150	pounds chalk.
3, 203⅛	pounds glue.
225½	pounds glycerine.
244	cans and boxes concentrated lye.
131¼	pounds mercury and its salts.
52	pounds spirits of nitre.
4, 619⅞	pounds potash, various.
61½	pounds sal ammoniac.
11, 231	pounds sal soda.
2, 938	pounds silicate of soda.
2	retorts.

PAINTS, OILS, ETC.

215¼	gallons benzine.
1, 111	gallons coal tar.
81¼	gallons drier.
1, 044	pounds kalsomine.

100½	gallons lacker.
337½	gallons oil, dressing.
5, 474¾	gallons oil, illuminating.
4, 749½	gallons oil, lubricating.
4, 500½	gallons oil, mixing paint.
8, 631¼	pounds paint, dry.
9, 903½	pounds paint, in oil.
100	gallons paint, in oil.
3, 473	gallons petroleum.
220	pounds lubricating compound.
339	pounds putty.
483 1/16	pounds shellac.
2, 438½	gallons turpentine.
274⅜	gallons varnish.
632	pounds zinc paint.
731½	pounds lampblack.
40, 599⅛	pounds white lead.
110	pounds litharge.
1, 412	pounds whiting.
1, 005	pounds axle grease.
4, 196¼	gallons gasoline.
571	gallons naphtha.
23½	gallons castor oil.
49	gallons paraffine.
20	pounds paraffine.

MISCELLANEOUS.

363	bags.
225	barrels.
12	baskets.
1	boat.
2, 333	boxes packing
121	kegs.
1, 954	tin cans.
1	set post harness, single.
1	set post harness, double.
7	horses.
2, 576	feet hose.
3, 165¾	pounds Japan wax.
25	pairs magazine slippers.
671¾	pounds packing, various.
2	pairs rubber legging.
3	rubber aprons.
12	rubber coats.
17	pairs rubber boots.
14	pairs rubber gloves.
1, 209½	pounds sheet rubber.
277	feet rubber tubing.
4	fonts rubber type.
1	set rubber type.
1	sleigh.
2	wagons.
289	parts of wagons.
2	engineer's transit.
2	water tanks.

452	powder canisters, 2-pound.
252	powder canisters, 5-pound.
2	wagon robes.
1	watchman's time detector.
27	buckets.
300	tin boxes.
3,370	pounds phosphate.
1	truck.
1	sprinkling cart.

MACHINES.

5	platform and hay scales.
1	sheostat.
1	pipe-cutting and threading machine.
4	screw-cutting machines.
21	drilling machines.
2	wood planing machines.
1	metal planing machine.
1	vertical boring machine.
2	magneto machines.
1	electro-plating machine.
19	milling machines.
1	cutting-off machine.
1	patent band re-sawing machine.
1	slotting machine.
1	mowing machine.
2	morticing machines.
3	drill-grinding machines.
3	profiling machines.
1	lead-lapping machine.
1	foot lathe.
1	hand lathe.
1	steam engine, Corliss, for Benicia Arsenal.
2	steam indicators.
1	"Detroit" lubricator.
1	steam hammer and anvil, complete, 1,200 pounds.
1	galvanometer.
2	elevators.
1	blower.
3	lawn sprinklers.
1	plant for manufacture of gas at national armory.
1	gas generator.
6	lawn mowers.
1	40-ton railroad truck scale.
2	force pumps.
4	engine lathes.
2	steam pumps.
4	steel boilers.
414	pounds brass tubes for steam fire-engine.

TOOLS, ETC.

1,322	brushes and sash tools.
2,550	files.
59,502	pounds grindstones.

1,444	tool handles, various.
100	ladles, 7-inch.
100	ladles, 2½-inch.
49	figures and letters.
155	oil cups and oilers.
385	saws.
25	saw blades.
40	scythes.
14	scythe snaths.
91	scythe stones.
251	shovels.
6	trucks.
6	vises.
68	wheelbarrows.
139	wrenches.
40	picks.
1	corn sheller.

APPENDIX 3.

Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the fiscal year ended June 30, **1884.**

CLASS I.

6	Gatling guns, 10-barrels, long, caliber .45.
2	Hotchkiss revolving guns, caliber 1.5.
5	Hotchkiss mountain guns, caliber 1.65.
22	3-inch rifled guns.
6	3.2-inch breech-loading, chambered, rifled guns.
8	light 12-pounder bronze guns.
8	30-pounder Parrott guns.
1	10-inch Rodman gun.
1	15-inch Rodman gun.
2	10-inch siege mortars.

CLASS II.

5	Gatling gun carriages and limbers.
2	1.5-inch Hotchkiss revolving gun carriages and limbers.
4	1.65-inch Hotchkiss mountain gun carriages.
30	3-inch gun carriages and limbers.
2	3.2-inch gun metal carriages and limbers.
3	3.2-inch gun metal carriages without limbers.
15	12-pounder gun carriages and limbers.
8	30-pounder gun carriages and limbers.
9	3-inch gun caissons and limbers.
2	Gatling gun limbers.
8	Laidley cavalry forges.
4	ammunition wagons for Hotchkiss gun.
1	tripod for Gatling gun.
2	24-pounder mortar beds.
2	10-inch mortar beds.
1	mortar wagon.

CLASS III.

72	harness bags.
1	carrying bar.
2	elevating bars.
6	baskets for mortar implements.
2	buckets for Hotchkiss gun.
39	iron sponge buckets.
5	wooden sponge buckets.
26	iron tar buckets.
76	gutta-percha water buckets.
11	papier-maché water buckets.

2	drag ropes.
4	fuse blocks.
28	fuse cutters.
4	fuse gimlets.
1	fuse gouge.
15	fuse mallets.
26	fuse plug wrenches.
10	fuse saws.
2	fuse setters, brass.
43	gunners' gimlets.
72	gunners' haversacks.
9	gunners' levels.
29	gunners' pincers.
8	gunners' quadrants.
45	pairs gunners' sleeves.

GUN SIGHTS.

3	breech sights, 3-inch gun.
8	breech sights, 30-pounder gun.
5	breech sights, mountain howitzer.
7	breech sights, 15-inch gun.
7	muzzle sights, 3-inch gun.
2	muzzle sights, 4.5-inch gun.
8	trunnion sights, 30-pounder gun.
6	handspikes, Gatling gun.
69	handspikes, maneuvering.
12	handspikes, shod.
80	handspikes, trail.
2	handspikes, wood.
36	sets harness, 2-lead horses.
53	sets harness, 2-wheel horses.
2	sets harness, 1-horse, Hotchkiss mountain gun.
7	sets harness, Laidley cavalry forge.
2	sets men's harness.
1	ladle and staff.
5	common lanterns.
21	globe lanterns.
6	magazine lanterns.
113	lanyards.
2	mauls.
10	paulins, 5 by 5 feet.
2	paulins, 6 by 10 feet.
5	paulins, 8 by 10 feet.
109	paulins, 12 by 15 feet.
26	pendulum hausses, 3-inch gun.
24	pendulum hausse pouches.
6	pendulum hausse seats.
12	plummets.
3	powder-funnels.
11	powder-measures.
79	priming-wires, field.
25	priming-wires, siege.
31	prolonges.
20	rammers and staves.
13	gun scrapers.

3	mortar scrapers.
50	securing-stakes.
15	shell-hooks.
16	shot-carriers.
4	spatulas.
168	sponge covers.
196	sponges and rammers.
42	sponges and staves.
1	sponge, wire-rope.
113	thumbstalls.
133	tompions.
21	tow hooks.
65	tube pouches.
63	vent covers, field gun.
32	vent covers, siege gun.
23	vent pieces.
21	vent punches.
1	water tub for 15-inch gun.
26	wipers, mortar.
27	worms and staves, field gun.
1	worm and staff, siege gun.

IMPLEMENTS FOR GATLING GUN.

3	covers for gun, caliber 1-inch.
9	covers for gun, caliber .45.
6	clamps for worm gear.
6	drifts.
152	feed cases.
7	headless shell extractors.
3	oscillators.
6	lock screw-drivers.
6	small screw-drivers.
6	T screw-drivers.
6	shell drivers.
6	wiping rods.
9	adjusting screw-wrenches.
6	pin wrenches.
6	rear-guide nut wrenches.

2	sets accessories Hotchkiss revolving gun.
7	covers Hotchkiss revolving gun.
3	covers Hotchkiss mountain gun.

Classes IV and V.

80	3-inch shot.
350	30-pounder shot.
200	8-inch shot.
60	15-inch shot.
10,000	1.5-inch dummy projectiles for blank cartridges.
3,550	1.5-inch shell and cartridge case.
2,350	1.65-inch shell and cartridge case.
1,248	3-inch shell.
48	4.5-inch shell.
81	12-pounder shell.

154	24-pounder mortar shell.
130	30-pounder shell.
180	100-pounder shell.
100	8-inch shell.
450	10-inch shell.
450	13-inch shell.
391	3-inch case-shot.
20	12-pounder case-shot.
50	30-pounder case-shot.
294	3-inch canister.
31	12-pounder canister.

CLASS VI.

3,453	Springfield carbines.
4,775	Springfield rifles.
40	Springfield cadet rifles.
30	Springfield long-range rifles.
17	Springfield shotguns.
765	Colts' revolvers.
24	Schofield's Smith and Wesson revolvers.
3	artillery sabers.
833	cavalry sabers.
30	musicians' swords.
44	non-commissioned officers' swords.
450	hunting knives.
81	riflemen's knives.

CLASS VII.

ARTILLERY ACCOUTERMENTS.

40	knapsacks.
7	saber belts.
7	saber-belt plates.

CAVALRY ACCOUTERMENTS.

520	canteens and straps.
1,600	canteen straps.
65	carbine cartridge pouches.
2,164	carbine slings.
945	carbine sling-swivels.
578	pistol cartridge pouches.
2,563	pistol holsters.
1,805	saber belts.
1,674	saber-belt plates.
519	saber-belt attachments.
100	saber-belt attachment slings.
1,865	saber knots.

INFANTRY ACCOUTERMENTS.

1,685	bayonet scabbards.
3,682	blanket bags.
5,731	blanket-bag shoulder-straps.

7,585	blankets and coat straps.
60	canteens and straps.
7,559	canteens.
6,669	canteen straps.
649	canteen covers.
100	canteen corks and chains.
243	carrying braces, pattern 1874.
4,398	cartridge belts.
5,184	cartridge-belt plates.
4,556	cartridge boxes.
6,070	clothing bags.
5,729	clothing bag straps.
6,003	gun slings.
5,229	haversacks.
1,911	haversacks and straps.
4,756	haversack straps.
445	hunting-knife scabbards.
6,559	knives.
6,138	forks.
6,049	spoons.
5,790	meat cans.
1,545	revolver belts.
75	sliding frogs.
6,571	tin cups.
28	valise straps.
4,001	waist belts.
3,873	waist-belt plates.
261	waist belts and plates, non-commissioned officers' and musicians'.

APPENDAGES.

466	brushes and thongs.
7,196	headless shell extractors.
6	field cases for shotgun supplies.
4	powder chargers.
6	shotgun outfits.
1	rifle cleaner.
7,299	screw drivers.
1	clamp-screw driver, rear sight.
17	screw drivers, shotgun.
513	screw-drivers, revolver.
286	spring vises.
1,148	tumbler punches.
38	wipers, rod bayonet.
18	wiping rods, sectional shotgun.
8,867	wiping rods, wood.

HORSE EQUIPMENTS.

3,386	cavalry curb bridles.
566	watering bridles.
2,000	bridle ornaments.
142	carbine-sockets.
535	carbine-sockets and straps.
1,072	cinchas or hair girths.

260	cincha straps.
1, 326	coat straps.
52	cruppers.
386	curb bits.
50	curb chains.
74	curb straps.
3, 298	curry combs.
38	forage-sacks.
12	girths.
2, 419	halters and straps.
128	halter chains.
1, 246	halter headstalls.
3, 349	halter straps.
5, 066	horse brushes.
1, 193	horse covers.
2, 017	lariats.
956	double spring hooks.
923	links.
2, 990	nose bags.
2, 309	picket pins.
1, 077	saddles.
78	saddle bags, canvas.
19	saddle bags, leather, Cal. pattern.
527	saddle bags, leather.
50	saddle blankets, blue.
4, 160	saddle blankets, gray.
42	saddle blankets, red.
35	saddle cloths, felt.
80	saddle cloths, hair.
903	side lines.
84	side-line fasteners.
42	spurs and straps, Mills'.
2, 837	spurs.
4, 054	spur-straps.
741	stirrups.
18	stirrups with guidon sockets.
798	stirrup straps.
1, 847	surcingles.
12	sweat leathers.

CLASS VIII.

SMALL-ARM AMMUNITION.

974, 000	carbine ball cartridges.
406, 826	revolver ball cartridges.
173, 400	revolver blank cartridges.
3, 718, 750	rifle ball cartridges.
407, 000	rifle blank cartridges.
1, 911, 050	round balls.
728, 000	carbine bullets.
107, 000	revolver bullets.
4, 604, 450	rifle bullets.
500	percussion caps.
6, 833, 000	cartridge primers.
4, 010	rifle cartridge shells.

15,145	shotgun cartridge shells.
15,300	pounds No. 8 shot.
2,419,500	carbine cartridge wads.
613,150	shotgun cartridge wads.

AMMUNITION FOR CANNON.

5,089	blank cartridges, ½-pound charge.
1,230	blank cartridges, 1-pound charge.
4,998	blank cartridges, 6-pounder gun.
20,942	blank cartridges, 3.inch gun.
23,567	blank cartridges, light 12-pounder gun.
500	blank cartridges, heavy 12-pounder gun.
3,100	blank cartridges, mountain howitzer.
598	assorted paper fuses.
111	assorted wood fuses.
30,000	pounds cannon powder.
12,500	pounds hexagonal powder.
210	pounds meal powder.
15,400	pounds mortar powder.
52,627	pounds rifle powder.
10,000	Hotchkiss' cartridge-case primers.
4,000	electric primers.
127,592	friction primers.
10,000	Hotchkiss' cartridge-case wads.
360	brass fuse-plugs.

CLASS IX.

2	aiming stands.
4	aiming sights.
200	portable arm racks.
41	assorted blocks.
8,261	marksman's buttons.
1	capstan.
10	capstan bars.
4	capstan hand ropes.
1	sling cart.
3	sling chains.
126	assorted chocks.
14	disks.
231	signal flags.
188	streamers.
2	gin-blocks.
1	garrison gin.
99	halyards with screw eyes.
1	Cushing's portable harness-rack.
4	hydraulic jacks.
1	intrenching tool.
2	plane-tables.
7	gun platforms.
6	mortar platforms.
2	differential pulleys.
21	assorted rollers.
7	shifting-planks.
126	shot marks.
6	skids.

1	cannon slings.
1	brass stadia.
1	stadia bag.
3	Laidley target-axes.
3	Brinton targets.
17	Cushing targets.
208	Laidley's revolving targets.
33,541	paper targets.
7,944	target centers.
6	Laidley's target-clamps.
310	Laidley's target cross-pieces.
123	Laidley's target frames.
1,251	target frames.
20	target handles.
10,145,000	target pasters.
100	target plates.
6	target trucks.
10	Cushing's target truck frames.
311	target uprights.
9	trace ropes.
1	sling cart wheels.
16	truck wheels.

RELOADING TOOLS, ETC.

79	sets reloading tools.
147	combination anvils.
61	ball molds (4 balls).
101	brush wipers.
26	brush wipers for shotgun cartridges.
12	powder canisters.
48	crimping-die caps.
10	bench charges, reloading tool.
9	adjustable powder chargers.
110	adjustable powder and shot chargers.
6	crimping dies.
150	crimping and reloading dies.
6	reloading dies.
167	resizing dies.
170	drifts.
26	drifts for shotgun shells.
17	primer extractors.
647	extractor pins.
2	extractor screws.
67	funnels.
6	funnels, No. 20.
1	key and washer for powder charger.
52	melting ladles.
53	pouring ladles.
149	mallets.
66	oil cups.
8	priming tools, Bridgeport.
71	priming tools, Frankford.
205	priming-tool pins.
11	priming-tool spindles.
1	primer punch.

172	reloading punches.
106	resizing punches.
1	resizing-die socket.
9	safety sockets.
71	shell scrapers.
1	primer setter.
22	strainers.
104	washers.
45	wiping rods.

Class X.

PARTS OF CLASS I.

6	Gatling-gun firing pins.
702	gas checks.

PARTS OF CLASS II.

4	ammunition chests.
1	axle body.
1	bolster.
36	bolts and nuts.
10	key bolts.
6	rear hurter bolts, chassis.
8	elevating screws.
8	carrying hooks, chassis.
32	keys and chains.
6	stay-pin keys.
12	linchpins.
32	stay pins.
2	handspike pawls.
7	iron sponge and rammer props.
42	poles.
2	pole-yokes.
1	rail.
3	cavalry forge shafts.
10	Hotchkiss mountain gun shafts.
4	single-trees.
2	splinter bars.
5	caisson stocks.
36	wheels.
1	wheel, Archibald pattern.
1	wheel for Gatling gun, Colt's pattern.
23	wheels for field and siege carriages.
10	wheel shoes.

PARTS OF CLASS III.

11	artillery curb-bits.
2	breast-collars.
2	breechings.
2	breech straps.
26	artillery bridles.
740	brass-plated buckles.
1, 568	iron roller buckles.

14	collars.
30	curb chains.
12	cruppers.
60	artillery halters and straps.
40	brass loops.
14	nose bags.
26	pole pads.
36	pole straps.
54	rammer heads.
107	rosettes for artillery bridles.
2	pack saddles.
12	seats for drivers' saddles.
2	brush sponges.
461	woolen sponges.
42	pieces woolen sponges.
27	sponge heads.
4	artillery stirrups.
4	lead traces
16	patent splinter-bar traces.
2	wheel traces.
40	valise straps.
94	whips.

PARTS OF CLASS IV.

236	copper bands for shell.
726	sabots.
75	sabot-coppers.
250	sabot-leathers.
100	tin straps.

PARTS OF CLASS VI.—PARTS OF SPRINGFIELD CARBINE.

6	barrels.
64	bands.
42	butt-plates.
34	butt-plate screws.
215	front-sights.
95	front-sight covers.
25	front-sight pins.
2,738	jointed ramrods.
260	rear sights.
27	rear-sight bases.
35	rear-sight leaves.
660	stocks, wood part.
6	swivel bar rings.

PARTS OF SPRINGFIELD RIFLE.

2	lower bands.
2	upper bands.
69	band springs.
3	barrels.
403	bayonets.
62	bayonet clasps.
140	bayonet-clasp screws.

10	breech blocks.
187	breech-block caps.
758	breech-block cap screws.
30	breech screws.
621	bridles.
708	bridle screws.
62	butt plates.
222	butt-plate screws.
143	cam latches.
1,047	cam-latch springs.
2,226	ejector springs.
2,309	ejector-spring spindles.
145	ejector studs.
2,240	extractors.
3,650	firing pins.
801	firing-pin screws.
349	front sights.
424	front-sight pins.
60	guard bows.
219	guard-bow nuts.
25	guard-bow swivels.
172	guard-bow swivel screws.
1	guard plate.
625	guard screws.
56	hammers.
140	hinge pins.
45	hinge-pin studs.
125	locks.
45	lock plates.
433	main springs.
69	main-spring springs.
45	main-spring swivel rivets.
823	pistol grips, metal.
315	pistol grips, wood.
42	pistol-grip screws.
113	ramrods.
103	ramrod stops.
532	rear sights.
154	rear-sight base screws.
36	rear-sight base springs.
307	rear-sight leaves.
3,694	rear-sight plates, buckhorn.
36	rear-sight joint pins.
281	rear-sight slide blocks.
502	rear-sight slide gibs.
254	rear-sight slide plates.
6,510	rear-sight slide screws.
65	rear-sight slide springs.
35	rod-bayonet spring.
767	sears.
1,121	sear screws.
629	sear springs.
853	sear-spring screws.
706	side screws.
82	side-screw washers.
1	stock, complete.

429	stocks, wood part.
334	tang screws.
37	thumb pieces.
2	stock tips.
14	tip screws.
1, 300	triggers.
72	trigger screws.
966	tumblers.
183	tumblers, swivelled.
935	tumbler screws.

PARTS OF HOTCHKISS RIFLE.

25	barrels, navy.
6	butt plates.
5	cartridge followers.
10	cartridge stops.
2	cartridge-stop pins.
20	cocking pieces.
4	cut-offs.
4	cut-off escutcheons.
12	cut-off escutcheon screws.
50	extractors.

PARTS OF HOTCHKISS CARBINE.

100	stocks, wood part.

PARTS OF COLT'S REVOLVER.

125	back straps.
293	back-strap screws.
33	bolts.
86	bolt screws.
238	center pins.
103	center-pin bushings.
68	center-pin catch screws.
246	center-pin screws.
5	cylinders.
158	ejector heads.
80	ejector rods.
233	ejector springs.
24	ejector tubes.
101	ejector-tube screws.
74	firing pins.
74	firing-pin rivets.
10	front sights.
5	gates.
26	gate catches.
87	gate-catch screws.
175	gate springs.
119	guard screws, long.
88	guard screws, short.
123	hammers.
55	hammer cams.
100	hammer rolls.

55	hammer-roll rivets.
92	hammer screws.
134	hands.
226	hand springs.
97	main springs.
110	main-spring screws.
107	sear springs.
45	sear-spring screws.
18	sear and stop-bolt screws.
205	sear and strop-bolt springs.
76	sear and stop-bolt spring screws.
143	triggers.
87	trigger screws.

PARTS OF SCOFIELD'S SMITH AND WESSON REVOLVER.

3	base pins.
13	extractors.
10	extractor springs.
10	extractor stems.
10	guard screws.
10	hammers.
4	hands.
2	hand pins.
6	hand springs.
4	joint pivots.
3	joint-pivot screws.
2	lifters.
13	main springs.
3	main-spring swivels.
4	pawls.
6	pawl pins.
10	pawl springs.
3	stops.
3	stop-pins.
3	stop springs.
12	strain screws.
6	triggers.
6	trigger pins.
10	trigger springs.

PARTS OF BREECH-LOADING SHOTGUN.

54	extractors.
50	stocks, wood part.

PARTS OF SWORDS.

1	musician's steel scabbard.
7	officers' nickel-plated scabbards.

PARTS OF CLASS VII.

5, 502	brass-bar buckles.
2, 992	brass-wire buckles.
1, 340	iron-bar buckles.

1,943	iron roller buckles.
144	gross brass escutcheon-pins.
204	halter bolts.
900	halter rings.
45	halter rings, swivelled.
904	halter squares.
6	hook straps.
40	leather lacing-thongs.
1,040	ovals.
2,444	brass rings.
444	iron D rings.
1,464	iron rings.
96	saber belt studs.
36	saddle-bag studs.
24	shields.
704	brass snap-hooks.
24	link snaps.
202	side-line snaps.
30	carbine sling swivel springs.
2,098	brass foot staples.
4,252	brass staples for rings.
74	yards webbing, 3.5-inches wide.
560	yards linen webbing, 4 inches wide.
84	yards webbing, 4.5 inches wide.
48	yards webbing, 7.5 inches wide.

PARTS OF CLASS VIII.

7,300	cartridge bags, ½-pound charge.
500	cartridge bags, 1-pound charge.
3,000	cartridge bags, 2-pound charge.
3,800	cartridge bags, 6-pounder gun.
6,000	cartridge bags, 12-pounder gun.
4,000	cartridge bags, mountain howitzer.
500	cartridge bags, 30-pounder gun.
9,700	cartridge bags, 3-inch gun.
1,150	cartridge bags, 4½ inch gun.
2,025	cartridge bags, 8-inch columbiad gun.
1,700	cartridge bags, 8-inch rifled gun.
1,500	cartridge bags, 10-inch gun.
500	cartridge bags, 15-inch gun.

PART SECOND: CLOTH, ROPE, THREAD, ETC.

201	yards burlaps.
120	yards canvas.
2	yards carpeting.
10,508½	yards cotton cloth.
15¼	yards lanyard cord.
28	pounds rocket cord.
9	pieces sash cord.
163⅞	pounds sash cord.
195	pounds waste cotton.
12	yards flannel.
40	pounds curled hair.
136¾	pounds marline.

2, 444	pounds rope, hemp and manila.
10	fathoms bolt rope.
20	fathoms ratling sizing.
10	fathoms ratling stuff.
200¼	pounds linen thread.
12	spools linen thread.
10½	pounds saddlers' thread.
784	pounds shoe thread.
40	pounds tow.
244½	pounds twine.
52	pounds yarn.

IRONMONGERY.

6	pounds sheet brass.
20	pairs iron butt hinges.
13, 838	horse shoes.
1, 369	pounds horse-shoe nails.
1, 746	pounds bar iron.
1, 039¾	pounds hoop iron.
159	pounds sheet iron.
2	pieces ½-inch plate iron.
50	keys.
2	iron ladles.
65	lead slabs, target.
45	pounds copper nails.
4, 675	pounds iron nails.
240	Japanned nails.
240	saddle nails.
336	padlocks.
8	cast-iron posts.
289½	pounds brass rivets and burrs.
826	pounds copper rivets and burrs.
102½	pounds iron rivets and burrs.
1	gross screw-eyes.
180⅛	gross brass screws.
232	gross iron screws.
1	gross shields.
145	pounds solder.
400	pounds spikes.
947	pounds bar steel.
6, 000	copper tacks.
30	papers copper tacks.
207½	ponnds copper tacks.
907, 500	iron tacks.
987	papers iron tacks.
200	sheets tin.
500	feet wire gauze.
500	feet kerite wire.
50	pounds iron wire.
253	pounds sheet zinc.

LEATHER, ETC.

1, 165	sides bridle leather.
10	sides collar leather.

4	sides enamelled leather.
25,240	pounds harness leather.
3	sides lacing leather.
2½	pounds calf-skin.
25	sheep-skins.
267	quarts leather blacking
5	pounds ingredients leather blacking.
344½	pounds black wax.
13	ounces bristles.

LUMBER.

7,869	feet boards.
200	feet plank.
2,920	feet scantling.
833	feet timber.
12	pieces timber.

CLEANING, HEATING, ETC.

38	bath bricks.
346	corn brooms.
½	pint browning mixture.
16	counter dusting-brushes.
5	feather dusting-brushes.
5	wire-scratch brushes.
7	button brushes.
6	button sticks.
74	pounds candles.
50	chamois skins.
42	boxes cleaning material.
1	cleaning plate.
9,140	pounds coal.
57¾	quires crocus cloth.
11	pieces emery cloth.
932	quires emery cloth.
233½	quires emery paper.
10	pounds emery.
10	pounds lampwicking.
1	gross matches.
38	pounds polishing materials.
56	pounds scouring materials.
522	pounds rottenstone.
176	quires sandpaper.
175	pounds bar soap.
3,344½	pounds castile soap.
155	pounds sponge.
871	papers tripoli.
5	browning wheels.
18	buffing wheels.

MATERIALS FOR OFFICE USE.

2	cans blacking, stencil outfit.
1	can with lamp and cup for sealing-wax.
190	instruction books.
3	camelshair brushes.

22	fitch brushes.
50	stencil brushes.
3	bottles hektograph ink.
4½	pounds drawing paper.
20	pounds log paper.
98	pounds petroleum paper.
1,750	pounds wrapping paper.
8	seal stamps.
85	pounds sealing-wax.
1	stencil plate, company.
7	stencil plates, letters and figures.
10	sets stencil outfits.
11	tape-lines or measures.

LABORATORY STORES.

4	pints muriatic acid.
136	pounds sulphuric acid.
109	gallons alcohol.
100	pounds gumarabic.
145¼	pounds beeswax.
5	pounds borax.
1	camera-obscura head.
42	pounds camphor.
90	pounds ammoniated copper.
1	barrel of flour.
115	pounds glue.
20	pounds lard.
15	boxes concentrated lye.
76½	pounds mercury.
1,000	pounds niter.
960	pounds laboratory paper
20	pounds black pepper.
¼	barrel plaster paris.
250	pounds potash.
30	pounds rosin.
5	pounds sal-ammoniac.
6	hair sieves.
35	pounds nitrate of strontia.
367	pounds sulphur.
200	pounds tallow.
30	pounds tobacco.
368½	pounds Japan wax.
24	gallons whisky.

OILS, PAINTS ETC.

58	pounds asphaltum.
353	gallons coal tar.
36¼	gallons Japan drier.
10	pounds patent drier.
5	pounds walnut graining.
156	gallons lacker.
22	pounds lampblack.
50	pounds red lead.

3, 245	pounds white lead.
9	pounds extract logwood.
$99\frac{1}{4}$	quarts cosmoline oil.
7, 126	pounds harness oil.
$325\frac{1}{2}$	gallons kerosene oil.
15	gallons lard oil.
$861\frac{107}{120}$	gallons linseed oil.
$1\frac{1}{2}$	gallons lubricating oil.
$220\frac{1}{2}$	gallons neatsfoot oil.
62	gallons neutral oil.
5	gallons olive oil.
$834\frac{3}{4}$	gallons sperm oil.
$1,886\frac{1}{2}$	pounds black paint.
31	pounds ivory-black paint.
40	pounds brown paint.
1, 075	pounds green paint.
855	pounds lead-color paint.
4, 252	pounds metallic paint.
3, 977	pounds olive paint.
$151\frac{0}{5}$	pounds red paint.
1215	pounds oriental red.
10	pounds venetian red.
10	pounds vermillion.
1	gallon chrome yellow.
10	boxes stencil paste.
90	pounds putty.
20	pounds shellac.
28	pounds sienna.
10	pounds soda.
2	gallons tar.
809	gallons turpentine.
40	pounds umber.
5	gallons asphalt-varnish.
3	gallons coach varnish.
20	gallons copal varnish.
21	gallons Japan varnish.
$202\frac{1}{2}$	pounds whiting.

MISCELLANEOUS.

456	arm chests.
1, 383	wooden powder barrels.
2	waste-paper baskets.
1	boat.
94	bottoms for reloading tool boxes.
55	reloading tool boxes.
2	sponge boxes.
213	tin cans.
2, 372	powder canisters.
1	specimen case.
26	chamois-skin saber cases.
12	chamois-skin sword cases.
510	pounds wheel grease.
72	powder kegs.
2	washing troughs.

MACHINES, ETC.

2	arbors.
2	diameter calipers.
1	diameter gauge.
6	crusher gauges.
4	pressure gauges.
10	assorted ring gauges.
1	star gauge.
1	rifle guide for star gauge points.
1	engine lathe.
1	hand lathe.
6	plugs for crusher-gauge housings.
1	set star-gauge points.

TOOLS.

1	adze.
1	anvil.
20	aprons.
1	auger.
6	brad awls.
12	peg awls.
712	saddlers' awls.
15	seat awls.
12	stub awls.
291	awl-handles.
77	awl-handles, patent.
10	felling-axes.
3	hand-axes.
5	axe-handles.
1	bellows, smiths'.
1	extension bit.
23	bits for brace.
2	dredging boxes.
7	braces.
3	brushes for oiling leather.
361	paint brushes.
30	paste brushes.
131	sash brushes.
1	varnish brush.
9	iron buckets.
22	wooden buckets.
3	calipers, smiths'.
4	hand carts.
23	chalk lines.
6	chalk-line reels.
1	channeller.
5	chains, surveyors'.
11	chisels.
4	chisel handles.
29	clamps, saddlers'.
31	claw tools.
33	compases.
6	counter sinks.
1	iron creaser.
43	wooden creasers.

1	diamond, glaziers'.
2	dippers.
5	turning dogs.
1	drill stock.
56	edge tools.
12	fids.
720	files.
20	file handles.
1	straining fork.
12	rocket formers.
4	copper funnels.
1	furnace, tinners'.
5	gauges.
10	gimlets.
4	grindstones.
1	grindstone arbor and crank.
78	assorted hammers.
2	sledge hammers.
14	hammer handles.
30	hatchets.
19	horses, saddlers'.
7	jackscrews.
153	assorted knives.
1	drawing knife.
24	gauge knives.
23	splitting knives.
3	levels.
22	mallets.
6	marline spikes.
5,010	needles.
39	papers needles.
82	nippers.
1	oil can.
1	oil cup.
4	oil droppers.
5	oilers.
28	oil stoves.
6	palms.
1	pickaxe.
2	pickaxe handles.
5	pincers.
5	pin-drivers.
9	planes.
2	plane irons.
4	pliers.
3	glue-pots.
6	prickers.
4	pricking carriages.
18	pricking wheels.
1	pritchel.
88	assorted punches.
79	spring punches.
4	punching blocks.
131	rasps.
7	rivet sets.
1	rounding iron.

95	rules.
44	sandstones.
11	saws.
3	saw sets.
3	scales.
21	scissors.
1	scoop.
6	iron scrapers.
4	paint scrapers.
30	screw-drivers.
1	scythe.
2	scythe-snaths.
1	scythe-stone.
46	shears.
16	rubber shoes.
5	assorted shovels.
2	sickles.
2	slickers.
11	pairs magazine slippers.
3	squares.
29	thimbles.
12	thimbles and hooks.
6	ticklers.
2	tool bags for saddlers and smiths' tools.
6	tongs.
8	assorted vises.
28	assorted wrenches.

APPENDIX 4.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1884, under sections 1661 *and* 1667, *Revised Statutes United States, and regulations established in conformity therewith.*

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,439 13
Arkansas	7	3,107 39
California	8	3,551 31
Colorado	3	1,331 74
Connecticut	6	2,663 48
Delaware	3	1,331 74
Florida	4	1,775 65
Georgia	12	5,326 96
Illinois	22	9,766 09
Indiana	15	6,658 70
Iowa	13	5,770 87
Kansas	9	3,995 22
Kentucky	13	5,770 87
Louisiana	8	3,551 31
Maine	6	2,663 48
Maryland	8	3,551 31
Massachusetts	14	6,214 79
Michigan	13	5,770 87
Minnesota	7	3,107 39
Mississippi	9	3,995 22
Missouri	16	7,102 61
Nebraska	5	2,219 57
Nevada	3	1,331 74
New Hampshire	4	1,775 65
New Jersey	9	3,995 22
New York	36	15,980 88
North Carolina	11	4,883 05
Ohio	23	10,210 01
Oregon	3	1,331 74
Pennsylvania	30	13,317 40
Rhode Island	4	1,775 65
South Carolina	9	3,995 22
Tennessee	12	5,326 96
Texas	13	5,770 87
Vermont	4	1,775 65
Virginia	12	5,326 96
West Virginia	6	2,663 48
Wisconsin	11	4,883 05
Arizona Territory*	3	1,331 74
Dakota Territory*	3	1,331 74
Idaho Territory*	3	1,331 74
New Mexico Territory*	3	1,331 74
Montana Territory*	3	1,331 74
Utah Territory*	3	1,331 74
Washington Territory*	3	1,331 74
Wyoming Territory*	3	1,331 74
District of Columbia*	3	1,331 74
Total	428	189,995 00
Freights, &c		10,005 00
		200,000 00

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX 5.

Statement of ordnance and ordnance stores, &c., distributed to the militia from July 1, 1883, to June 30, 1884, under sections 1661 and 1667, Revised Statutes United States.

CLASS I.

2	10-pounder Parrott rifled guns, 3-inch bore.
1	12-pounder mountain howitzer.
4	3-inch breech-loading howitzers, with sights complete.
11	3-inch wrought iron rifled guns.
1	Lowell battery gun, caliber .45.

CLASS II.

1	carriage and limber for 12-pounder gun.
12	carriages and timbers for 3-inch guns.
4	carriages for 3-inch breech-loading howitzers, with implements and equipments.
1	carriage for Lowell battery gun, caliber .45.
4	caissons and limbers for 3-inch gun.

CLASS III.

4	copper funnels.
2	covers for Gatling gun.
4	drag ropes.
20	extractor hooks for Gatling gun.
8	fuse blocks.
14	fuse cutters.
13	fuse gouges.
12	fuse wrenches.
1	fuse plug wrench.
25	feed cases for Gatling gun.
56	gunners' haversacks.
23	gunners' gimlets.
21	gunners' pincers.
42	handspikes, trail.
73	lanyards.
45	priming wires.
27	prolonges.
20	pairs pole straps.
9	pole pads.
3	poles for 3-inch carriage.
30	paulins, 12 by 15 feet.

1	paulin, 8 by 12 feet.
14	pendulum hausses for field guns.
10	pendulum hausse seats for field guns.
26	pendulum hausse pouches for field guns.
4	powder measures, 1 pound.
58	sets artillery harness, 2 horses, wheel.
42	sets artillery harness, 2 horses, lead.
16	sponge buckets, iron.
10	sponges and rammers, 12-pounder gun.
2	sponges and rammers, 12-pounder mountain howitzer.
2	sponges and rammers, 6-pounder gun.
68	sponges and rammers, 3-inch rifle gun.
8	sponge covers, 12-pounder gun.
2	sponge covers, 6-pounder gun.
44	sponge covers, 3-inch rifled gun.
14	sponges, 3-inch rifled gun.
91	thumbstalls.
17	tar buckets, iron.
24	tube pouches.
8	tow-hooks.
13	tompions, for 3-inch rifled guns.
31	vent punches.
27	vent covers.
22	watering bridles.
15	worms and staves.
1	wheel, No. 1, spare.

Classes IV and V.

25	12-pounder shot, strapped.
49	12-pounder shell, strapped.
24	12-pounder spherical case, fully prepared.
30	3-inch shot.
465	3-inch shell.
155	3-inch case shot.
100	3-inch canister.
200	3-inch shrapnel for breech-loading howitzer.
200	3-inch shell for breech-loading howitzer.
4	3-inch dummy shot for breech-loading howitzer.
4	3-inch dummy cartridges for breech-loading howitzer.
1,000	metallic ball cartridges, Gatling gun, caliber 1 inch.
1,000	metallic canister cartridges, Gatling gun, caliber 1 inch.

Class VI.

4,707	Springfield rifles, caliber .45.
100	Springfield muzzle-loading rifled muskets, caliber .58.
250	Springfield carbines, caliber .45.
550	Colt's revolvers, caliber .45.
109	officers' swords.
82	non-commissioned officers' swords.
150	light-artillery sabers.
170	cavalry sabers.
416	bayonets.

CLASS VII.

APPENDAGES.

750	headless shell-extractors, caliber .45.

HORSE EQUIPMENTS.

178	bridles, curb, cavalry.
34	brush and shoe pouches.
300	carbine sockets and straps.
99	curry combs.
13	halters.
99	horse brushes.
34	links.
65	lariats.
272	nose-bags.
65	picket pins.
140	pairs spurs and straps.
79	pairs saddle-bags.
244	saddles, cavalry.
610	saddle blankets.
13	surcingles.
12	saddle cloths.

INFANTRY EQUIPMENTS.

6,870	bayonet scabbards.
100	blanket bags.
100	pairs blanket-bag shoulder straps.
100	pairs coat straps.
140	cap pouches.
60	canteens and straps.
4,175	cartridge belts and plates.
10,000	cartridge boxes.
7,210	gun slings.
100	sliding frogs for non-commissioned officers' waist-belts.
4,400	waist belts.
3,038	waist belts and plates.

ARTILLERY EQUIPMENTS.

60	leg guards.
88	whips, artillery.

CAVALRY EQUIPMENTS.

250	carbine slings.
250	carbine-sling swivels.
196	pistol holsters.
100	sword knots.
810	saber belts and plates.

CLASS VIII.

1,350	blank cartridges, 12-pounder gun.
1,000	blank cartridges, 12-pounder mountain howitzer.

500	blank cartridges, 6-pounder gun.
2,350	blank cartridges, 3-inch rifled gun.
157,000	rifle ball cartridges, caliber .50.
563,000	rifle ball cartridges, caliber .45.
5,000	revolver ball cartridges, caliber .45.
110,000	rifle and carbine blank cartridges, caliber .50.
365,000	rifle and carbine blank cartridges, caliber .45.
4,000	musket blank cartridges, caliber .58.
1,000	revolver blank cartridges, caliber .45.
230,000	bullets for Lowell battery gun, caliber .45.
8,000	round balls for Lowell battery gun, caliber .45.
1,500	practice cartridges, caliber .45
1,000	practice cartridges, round ball, caliber .45.
1,000	practice shells, caliber .45.
7,000	cartridge shells, caliber 45.
10,535	friction primers.
475	fuses.
10,000	lubricants for reloading Lowell battery gun, caliber .45.
180,000	primers for reloading Lowell battery gun, caliber .45.
80	sets reloaders for Lowell battery gun, caliber .45.

CLASS X.

PARTS OF SPRINGFIELD RIFLE, CALIBER .45.

17	breech blocks.
25	breech-block caps.
319	breech-block cap screws.
3	breech screws.
150	bridles.
246	bridle screws.
5	cam latches.
250	cam-latch springs.
276	extractors.
425	ejector springs.
6	ejector-spring spindles.
1	ejector stud.
1,375	firing pins.
1,144	firing-pin screws.
1,250	firing-pin springs.
10	guards.
25	guard bows.
25	guard-bow swivels.
25	guard-bow swivel screws.
10	guard screws.
4	hinge pins.
10	locks.
5	lower bands.
212	main springs.
12	main-spring swivels.
930	rear sights.
100	rear-sight slide-screws.
1	receiver.
102	ramrods.
90	sears.
230	sear springs.

221	sear screws.
96	sear-spring screws.
17	stocks.
1,180	screw drivers.
320	spring vises.
37	side screws.
129	tumblers.
344	tumbler screws.
390	tumbler punches.
30	tang screws.
30	upper bands.
10	wooden wiping rods.

PARTS OF SPRINGFIELD RIFLE, CALIBER .50.

20	barrels.
50	breech blocks.
115	breech screws.
50	breech block cap screws.
250	bridles.
350	bridle screws.
200	bayonet clasps.
300	bayonet-clasp screws.
150	butt-plate screws.
100	cam latches.
200	cam-latch pins.
500	cam-latch springs.
300	extractors.
1,400	ejector springs.
400	ejector-spring spindles.
50	ejector studs.
900	firing pins.
200	firing-pin screws.
25	front sights.
150	guards.
50	guard bows.
100	guard-bow swivels.
100	guard-bow swivel screws.
125	guard screws.
25	guard plates.
50	guard-bow nuts.
30	hammers.
150	hinge pins.
25	locks.
20	lock plates.
175	lower bands.
45	main springs.
300	main-spring swivels.
300	main spring swivel rivets.
50	receivers.
50	ramrods.
130	rear-sight bases.
500	rear-sight leaves.
500	rear-sight leaf screws.
450	rear-sight leaf slides.
200	rear-sight springs.

300	rear-sight joint screws.
225	rear-sight base screws.
375	sears.
150	sear springs.
300	sear screws.
200	sear-spring screws.
600	stocks.
25	spring vises.
500	side screws.
500	tumblers.
325	tumbler screws.
100	tip screws.
25	thumbpieces.
100	trigger screws.
150	upper bands.
300	upper-band swivels.
600	upper-band swivel screws.

PARTS OF SPRINGFIELD CARBINE, CALIBER .45.

10	bands.
10	breech blocks.
6	breech screws.
10	cam latches.
12	extractors.
50	ejector springs.
12	ejector-spring spindles.
2	ejector studs.
50	firing pins.
10	guards.
20	guard screws.
8	hinge pins.
10	locks.
10	rear sights.
2	receivers.
10	stocks.
24	side screws.
20	swivel bases.
10	swivel-base rings.
10	swivel bars.
10	tang screws.

MISCELLANEOUS.

2	sets reloading tools.
4	cartridge-bag formers, for 3-inch breech-loading howitzer.

CLASS X.—VIII.

400	cartridge bags, 16-ounce, for 3-inch breech-loading howitzer.
400	cartridge-bag followers, for 3-inch breech-loading howitzer.

APPENDIX 6.

Statement of ordnance, ordnance stores, &c., distributed to the Territories and States bordering thereon, from July 1, 1883, *to June* 30, 1884, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.

100	Springfield rifles, caliber .50.
100	leather bayonet scabbards.
100	cartridge boxes.
100	waist belts and plates.
5,000	rifle ball cartridges, caliber .50.

APPENDIX 7.

Statement of ordnance and ordnance stores, &c., distributed to colleges from July 1, 1883, *to June* 30, 1884, *under section* 1225, *Revised Statutes United States, as amended by act approved July* 5, 1876.

CLASS I.

6	3-inch wrought-iron rifled guns, model 1861.

CLASS II.

6	carriages and limbers for 3-inch guns.
2	caissons and limbers for 3-inch guns.

CLASS III.

6	gunners' haversacks.
6	handspikes, trail.
12	lanyards.
6	priming wires.
6	paulins, 12 by 15 feet.
2	pendulum-hausses.
2	pendulum-hausse seats.
2	pendulum-hausse pouches.
12	sponges and rammers for 3-inch rifled guns.
12	sponge covers for 3-inch rifled guns.
6	tube pouches.
12	thumbstalls.
6	tompions.
6	vent covers.
1	worm and staff, field.

CLASS VI.

593	Springfield cadet rifles, caliber, .45.
36	non-commissioned officer's swords.

CLASS VII.

745	cartridge boxes.
593	bayonet scabbards.
593	waist belts and plates.
198	waist belt plates.
36	shoulder belts and plates, N. C. O.

CLASS VIII.

200	blank cartridges for 12-pounder gun.
800	blank cartridges for 6-pounder gun.
500	blank cartridges for 3-inch gun.
5, 000	carbine ball cartridges, caliber .50.
14, 000	carbine ball cartridges, caliber .45.
5, 000	carbine blank cartridges, caliber .50.
14, 000	carbine blank cartridges, caliber .45.
4, 500	friction primers.

APPENDIX 8.

Report of action taken under the act of March 3, 1881, *during the fiscal year ended June* 30, 1884.

SOLD.

To J. W. Frazier.

1883.			
Oct.	11.	24,300 pounds musket powder from broken-up ammunition, at 8 cents per pound	$1,944 00

To E. I. Du Pont de Nemours & Co.

Nov.	19.	11,160 pounds musket powder from broken-up ammunition, at 8 cents per pound	892 80

To. J. W. Frazier.

Dec.	18.	1,600 20-pounder Parrott shells, 26,400 pounds, at 5 cents per pound	1,320 00
		800 20-pounder Parrot case shot, 14,800 pounds, at 5 cents per pound	740 00

To E. I. Du Pont de Nemours & Co.

1884.			
June	23.	28,200 pounds unserviceable powder at 3 cents per pound	$846 00
		10,478 pounds unserviceable powder at 3¾ cents per pound	392 92
		Total proceeds	6,135 72

PURCHASED.

From South Boston Iron Works.

1883.			
July	25.	250 4.2-inch Butler shot, at $7.60 each	$1,900 00
Nov.	13.	250 3-inch Butler shot, at $2.79 each	697 50
		250 3-inch Butler shells, at $2.62 each	655 00
		300 4.5-inch Butler shot, at $6.65 each	1,995 00
		250 4.5-inch Butler shells, at $6.87 each	1,717 50

From West Point Foundry Association.

1883.			
Nov.	13.	250 3-inch Butler shot, at $2.79 each	697 50
		250 3-inch Butler shells, at $2.62 each	655 00
		300 4.5-inch Butler shot, at $6.65 each	1,995 00
		250 4.5-inch Butler shells, at $6.87 each	1,717 50

From E. I. Du Pont de Nemours & Co.

1883.			
July	1.	82,272¾ pounds musket powder, at 22 cents per pound	18,100 00
		10,000 pounds cannon powder, at 22 cents per pound	2,200 00
Nov.	2.	1,000 pounds hexagonal powder, at 25 cents per pound	250 00
1884.			
Jan.	25.	10,000 pounds sphero-hexagonal powder, at 25 cents per pound	2,500 00
March	11.	4,000 pounds granulated powder, at 18 cents per pound	720 00
April	29.	10,000 pounds sphero-hexagonal powder at 25 cents per pounds	2,500 00

From Bernard Peyton.

1884.			
Jan.	12.	10,000 pounds spehro-hexagonal powder, at 25 cents per pound	2,500 00
		9,871½ pounds hexagonal powder, at 26 cents per pound	2,566 58
		Total purchased	43,366 59

APPENDIX 9.

THE OXIDATION OF METALLIC PARTS OF THE SPRINGFIELD RIFLE.

BY LIEUT. COL. A. R. BUFFINGTON, ORDNANCE DEPARTMENT.

NATIONAL ARMORY,
Springfield, Mass., October 7, 1884.

SIR: Within a few days past I have been called upon by the Department for remarks relative to the "Bower-Barff process" of oxidizing the surface of iron and steel for preservation. To-day a representative of the parties controlling this process called upon me with specimens of their work, one a piece of gun barrel. In this way the subject has again been called to attention, at the same time the discovery is made, by a comparison of work and a fuller knowledge of the Barff process, that a method now in use at this armory is superior to it for the oxidation of parts of small arms. Six or seven years ago the Barff process, so far as my knowledge extends, was made known in this country, and attracted my attention relative to the oxidation of parts of small arms, but my interest extended no further; the difficulties attending the application and the high degree of heat required presenting obstacles I did not care to encounter experimentally. Some time after, either immediately before or after my change of station to the Watervliet Arsenal, I saw a public notice of a lecture in England in which it was stated the lecturer asserted the oxidation of iron and steel surfaces by the application of melted niter to be the magnetic or peroxide of iron. This or a similar notice was seen by one of the assistant officers at Watervliet, and he called attention to it and suggested that it be tried, which I instructed him to do with the lariat rings then manufactured. The result proving satisfactory, the rings were thereafter, up to the time of my leaving the arsenal, so colored.

About this time, being on a board of officers in New York with the late Colonel Benton, then in command of the armory, I called his attention to the subject with a view of applying the process to parts of small arms. He soon after died, and no further action was taken until some time after I succeeded him here, when my attention was again called to it by the master armorer observing the coloring of some metal, oxidized by niter, which I had brought with me, and asking how it had been done.

I then began experimenting, but succeeded only at first, with the help of one of the workmen, in securing a good color for the tip of rifle stocks. This part, malleable iron, had always been case-hardened. The case-hardening besides not coloring uniformly injured the files in fitting the rammer to the groove in assembling the arms. From this success, without entering into details, we have progressed until now tips, bands, band-springs, guards (fully assembled), and butt-plates are colored with the niter, and some experiments with barrels, after one (the first) rusting of the present browning process, would indicate that it is but a question of time until all metal parts of the rifle not requiring to be hardened, are so colored. But after the success with the tip when the process consisted simply in immersion in melted niter at about the melting temperature, after a blueing made in the ordinary way with heat (the malleable iron it was found required this preliminary blueing), a change was made. Whether the resulting satisfactory work is due to that change, or simply the result of more skill and judgment acquired by practice, as to degree of heat, time of immersion, &c., I am unable to say. The change consists in putting in the vessel with the melted niter a few pounds of peroxide of manganese. It was known to me that the presence of this mineral increased, without any chemical change in itself, the oxidizing properties of chlorate of potassa. Why not as well the nitrate of potassa? I tried it with the result as above. I have made no secret of this whole matter and it has already attracted the attention of one private arms company to the extent of coming here to see and learn the process. But it has occurred to me the armory process being superior in color (to the specimen of gun barrel shown), economy, and simplicity of application, and the heat required not affecting the temper, which the Barff process does, of tempered parts subjected to it, the United States should be secured in the use of this valuable method without payment of royalties, by the publication of the history of its use here. The simple oxidation of iron and steel by niter could not be patented, as books of chemistry have long ago published it, but the process as above described might be.

I therefore make this report with a view to its speedy publication. The method used here, in brief, is as follows: A cast-iron pot or vessel, open to the air, built into a furnace of fire-brick and heated from below, contains the niter and oxide of manganese at a temperature sufficiently high to cause ignition and combustion of a *pinch* of sawdust thrown upon the surface of the niter. The parts to be subjected to oxidation are suspended by wires from a stationary hook above the pot, in the center of the niter after immersing and moving them about through it so as to stir up the mixture. The parts are put in cold and *finished* excepting color, and left suspended as above from five minutes up, depending on the size and color required. After the lapse of the required time, or after satisfactory color is obtained, which can be determined by raising the charge out of the niter and looking at it, it is plunged into a vessel of hot water to cool and remove the adhering nitre; then into oil, completing the process.

Respectfully, your obedient servant,

A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance, Commanding.

CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

APPENDIX 10.

REPORT OF THE PRINCIPAL OPERATIONS AT THE ROCK ISLAND ARSENAL, ILLINOIS, DURING THE FISCAL YEAR ENDED JUNE 30, 1884.

LIEUT. COL. D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

(Two plates.)

SHOP H.—*An iron finishing shop for the armory.*—(PLATE I.)

This shop was commenced in August, 1878. The work done on it during the year is as follows:

STONE WORK.

The walls of the third story have been completed, thus completing the walls of the building. The stone for outside steps and platforms has been purchased and cut, and at the close of the year the construction of masonry for setting these steps and platforms, the building of area walls, and the grading areas and flooring the same with stone, was in progress. In connection with this work, the sewers with drain pipes and stench traps from areas and roof down-spouts and the water mains were being put in.

IRON WORK.

The beams for the iron roof frame have been purchased. The bar iron for the truss rods and other iron for the roof was manufactured in the Armory rolling-mill and in the Arsenal foundry.

The roof frame was entirely manufactured in the Arsenal shops during the winter, and at the close of the year nearly all of it had been set up on the building.

OTHER WORK DONE.

The brick and skewbacks (about 1,000,000) for the fire-proof arches were purchased and stacked under cover during the winter. There being no other demand for brick during the winter they were purchased at that season at about 15 per cent. less than summer prices.

The door and window frames and the window sash were manufactured in the Arsenal shops, and the latter glazed during the winter.

At the close of the year the work of putting on the roof sheathing, copper and slating, and putting in brick arches, and putting in windows, was in progress. This building will be entirely completed during the present fiscal year if the appropriation therefor proves sufficient.

SHOP K.—*A Finishing and stocking Shop for the Armory.*

(Plate 1.)

This shop was commenced in July, 1881. It is the last of the shops embraced in the plans for both the Armory and the Arsenal. The work done on it during the year is as follows:

STONE WORK.

The stone required for the first story has been purchased and cut, and the walls of this story completed. Rather more than three-fourths of the stone required for the second story has been purchased, one-half of it cut, and the walls of one-half of this story have been built. The stone for nearly one-half of the third story has been purchased also.

It may be worth while to state here that the third story walls contain all the large costly dimension stones of the entablature, which are difficult for the quarryman to provide. Generally not more than one-tenth of the product of a quarry will answer for these stones. For several years I have adopted the practice of allowing the contractor to quarry and furnish these stones whenever he can get them during the three or four years that he is furnishing stone from the date of commencing the building till the walls are finished. This enables him to get out these stones whenever he can along with the other cheaper stones, the rubble and ashlar, ship them and receive payment for them. It saves him the great expense of hauling them to distant ground, keeping them several years till they are wanted, and then hauling them back to the cars, and waiting several years for the price of them.

Instead of this he used generally to sell them to other parties if he could, or convert them into the cheaper grade of ashlar for the Arsenal shops, and when the construction of the third story was reached long vexatious delays would occur, while the contractor was quarrying and hauling out of his way large quantities of unsalable stone in order to get at the difficult stone required. The present custom enables him to ship at once as it is quarried nearly all of the sound and well-shaped stone of his quarry as he quarries it, and thereby saves to the United States a large percentage in the price. Also, as these stones require much labor in cutting, it enables me to have them cut during the several winters that the walls are in progress, and saves the considerable expense of taking on a large number of untried, and probably unskilled, cutters to hasten the cutting when the third story is reached. This practice has saved probably about $8,000 on the cost of the walls of each shop.

IRON-WORK.

All the iron beams for the second floor have been purchased during the year, fitted in the Arsenal shops, and put in position. The iron columns for the first story, the caps for the same, and the caps and bases for the second floor have been cast and fitted in the Arsenal shops and put in position.

WOOD-WORK.

All the lumber for this building has been purchased, and stacked under temporary sheds for seasoning.

A large amount of other work in connection with grading, drainage, paving the court, areas, and area-wall foundation has been done around this building.

STORE-HOUSE A.

(Plate I.)

This building was commenced in April, 1883, and is the first of the store-houses required for the Arsenal and Armory. At the beginning of the fiscal year the excavations for the basement had been completed, the foundations put in, and a portion of the basement story had been built. The work done on the building during the year was as follows:

STONE-WORK.

The basement story walls have been finished; the twenty-six stone piers required for sustaining the floors have been built; the second story has been built entire, and the third story nearly completed. The stone-work was in rapid progress at the close of the year with the view of completing this story and the next (thus completing the walls of the building) by November 1, 1884, in time to put on the roof before severe winter weather sets in.

IRON-WORK.

The massive caps, bases, and corbels for the tops of the stone piers, in connection with the first floor, were cast and finished in the Arsenal shops during the winter and have been put into the building. Drawings of this iron-work were furnished with my annual report of last year. At the close of the year the same iron-work for the second story and for the third floor was in progress and nearly completed.

WOOD-WORK.

All the lumber for the whole building has been purchased and stacked under temporary sheds for seasoning, and the heavy timbers and joists for the first and second floors have been framed and put in position, and were used as scaffolding for carrying the heavy traveling cranes, and tramways for transporting stone used in the construction of the walls of the building.

These floors are designed to support a load of 400 pounds. per square foot. Drawings showing their construction were furnished with my report of last year.

Work on this building is being rapidly pushed, with the intention of getting the iron roof frame on the building, and of completing the roof before December 1, 1884, in order to protect the valuable timber-work of the floors from the weather during the winter. It is expected that the building will be completed and ready for use by July 1, 1885, if the appropriation therefor proves sufficient.

REPAIRS OF BUILDINGS, IMPROVEMENT OF GROUNDS, AND GENERAL CARE AND PRESERVATION.

The work done under the head of repairs and care and preservation has been mainly:

The repairs necessary for the preservation of the extensive dams, gates, and machinery pertaining to the water-power and the transmission machinery.

Some rather expensive and absolutely necessary repairs to the Arsenal railroad.

Such repairs as were absolutely and immediately necessary for the preservation of buildings as far as the amount of the appropriation would permit.

Necessary repairs of the bridges to Rock Island and Moline.

The care and preservation of the extensive grounds and roads.

The substitution of an iron hood for the temporary wooden one on the Arsenal forging shop and foundry (Shop E), in compliance with the verbal instructions of the Chief of Ordnance, during his last visit to this Arsenal. This hood has a total length of 790 feet, is 15 feet wide, and the walls 8 feet high. The frame is of wrought iron, and its roof galvanized and corrugated sheet-iron.

When the building was completed in 1873, the appropriation being insufficient, the side walls were constructed of wood. This wood-work has now been removed, the side walls made of galvanized and corrugated iron in panels placed between pilasters 5 feet apart, in all respects like the hood of the rolling-mill armory, Shop F. The change has not only made the construction permanent in accordance with the original plan, but also adds much to the good appearance of the building.

The principal work done under the head of improvement of grounds has been as follows:

The work of grading of ground, construction of streets, laying walks, and planting trees around newly finished buildings, has been continued.

The ditching of the low swamp lands of the island has been continued.

The south shore of the island, from a point about 1,000 feet below the water-power dam down to near the powder magazine, a distance of nearly three-fourths of a mile, has been riprapped to prevent washing away. During the extreme high water of the last three years the water has come up to the overlying soft loam of the island, and waves caused by south winds across the water, which is wide at a high stage, was rapidly cutting away the shore. The greater part of the stone for the work was hauled from a dump made from the late excavations in the water-power canal, near its west end, and was hauled over mainly on the ice by enlisted men, with the Government teams during the winter, when other work was slack. A portion of the stone was taken from a rock cut, made in building West avenue, which is described, just below.

The principal item of work under this head has been the construction of West avenue from South avenue southward to the south shore of the island. (See Plate II.)

From the site of the new Storehouse A, the ground slopes suddenly southward down to a low swamp, subject to harmless overflows during freshets. This swamp terminates in a steep rise to the rock plateau at the site of the laboratory yard. I commenced a fill across this swamp with a portion of the excavations from Shop A, in 1873 and 1874. This fill has been completed during the year with the excavations from the basement of the Storehouse A, and with the cuttings from the rock cut made through the plateau near the laboratory yard. This cut was required in order to establish a suitable grade for West avenue. This fill is 900 feet long, 130 feet wide on top, and 11 feet deep at its deepest part (see cross-section on Plate II), and contains in all about 30,000 cubic yards. Its sides are smoothly riprapped with rock, as shown on the drawing.

The roadway of the avenue was then constructed on the fill and through the cut down to the river, with substantial stone gutters on both sides. This avenue is an important one as it is the road between the shops, the laboratories, and magazines, and has been well constructed. A profile of the roadway is also given on the drawing.

The fill at the sides of the avenue, each 50 feet wide from the avenue to the margins of the fill and cut, were covered and handsomely graded with loam saved from the excavations and rich earth hauled from the ditches in the swamps, and sodded. No trees are planted on the ground thus made, except along the margins of the fill and cut, in order to leave a view open from the railroads and growing city on the mainland, to a portion of the shops.

This is, I believe, the best improvement, in appearance, made on the island. Its good effect is improved by leaving out trees among surroundings where we have, I think, too many trees.

A walk has been built, as shown on the drawing, from the shops to the laboratory yard. It is constructed of beton, as described in my last annual report. So far as I can judge now, this walk will prove as durable as the best flag-stone walks. Its first cost is only 70 per cent. that of stone; it costs nothing for care and preservation, is much handsomer, and better also if it will last.

In connection with all of the above work, a site for laboratories has graded, elm trees planted between the proposed sites for the buildings, to protect them from each other in case of fire or explosions, and the grounds inclosed with a fence. The grading was difficult, as many high points of rock had to be blasted off, and much earth hauled in for grading. Holes had also to be blasted out for planting the trees.

A permanent railroad siding has also been built from the main track as far as Storehouse A. This is part of a track the whole of which is shown on Plate I. A considerable embankment was required, and it is built entirely of rock and handsomely riprapped.

I feel it my duty to invite the attention of the Chief of Ordnance to the fact that the appropriation allowed for this class of work for several years past has been much less than it ought to be. The utmost that is possible has been done to economize. It is nearly impossible that some improvement of grounds should not be carried on in connection with the construction of buildings in order to utilize materials excavated, finish grounds around the buildings, and furnish needed improvements for use in carrying on other work. Besides this the buildings, roads, and other improvements are now of such magnitude that they require fully ten times as much for their proper care and preservation as they did thirteen years ago, at which time the appropriation for this work was double that which has been allowed in the past few years.

I know of no better method of exhibiting this than by comparison. The extent of the work that ought to be done to keep in good order and repair streets, avenues, grounds, large bridges, shores of the island, railroads, gutters, walks, sewers, water-works, and the dams and gates, and other constructions pertaining to the water-power, is equal to the work of a similar kind done in a city of 10,000 inhabitants. In addition to this, the buildings and many other constructions taken care of by private owners in a city, must be kept in repair. I estimate that $9,000 ought to be expended in the coming year in repainting buildings and bridges alone, for their proper preservation.

MACHINERY AND SHOP FIXTURES.

The principal items of work under this head has been the manufacture of shafting and other fixtures for Shop G; the manufacture of new hangers and boxes, of the pattern described in my report of 1874, for

Shop C; the forging of heavy shafting for water-power machinery, the construction of a 50-ton track scales in the railroad track, and the addition of a few machines required for immediate use in the shops. The principal of these is a large sized band resawing machine for the wood-working shop.

ROLLING-MILL.

In my last report a description was given of some improvements in the fixtures of the rolling-mill for accomplishing more economical work, and these have been used with good success during the past year.

I would also report that a serious matter in running the mill heretofore has been the employment of skilled mill men. These men charged extortionate prices, could not be properly controlled, and gave much trouble. I succeeded last winter in getting along without them. A party of workmen, generally helpers, were taken from the regular force of arsenal employés, and carefully and slowly trained to do the work. They were men who would otherwise have been thrown out of employment during the winter, and the labor was valuable to them. A saving was effected on former prices of about 40 per cent. on blooming, and 28 per cent. on rolling.

No comparison can be made on heavy forgings, as none of these had been made before. They had been purchased at from 7½ to 9½ cents per pound. Those made last winter cost about 3.9 cents after the men had been trained, allowing ¾ of a cent for the scrap. This last work was however valuable in providing facilities for furnishing heavy forgings should they ever be required by the Department.

The work done was as follows:

	Pounds.
Blooms made from poor scrap	275,489
Bar-iron rolled	147,685
Shafting rolled, 3¼ inch	26,869
Shafting forged, 8½-inch	20,128
Shafting forged, 7½-inch	10,472
Shafting forged, 5½-inch	9,882

In this connection I would invite the attention of the Department to the facilities which the Arsenal has in steam-hammers, heavy press punches and shears, and good forging and machine-shop appliances for such heavy work as the manufacture of iron or steel field-carriages.

* * * * * * *

ROCK ISLAND BRIDGE.

I append hereto (Appendix B) a statement of the traffic by the public on the bridge during the year.

The only repairs of the bridge during the year other than those necessary for ordinary care and preservation were some extensive repairs of the timber-crib of the draw-pier, some improved machinery for the connections between the railroad deck and the adjoining spans, the purchase of lumber for renewing roadways, and a new coat of macadam, 9 inches deep, on 800 feet of Fort Armstrong avenue. The traffic of heavy teams on the bridge has become so great as to require a renewal of the macadam on the avenue about once in two years, and of the oak floors of the wagon-road on the bridge about once in four years.

WATER-POWER.

The work done on the water-power during the year in carrying out a special contract made with the Moline Water Power Company in 1882, has been as follows:

The new dam for the use of the Moline Company, with iron gates and fixtures, has been completed in accordance with the contract.

The deepening of the canal for the use of the Moline Company has been completed in accordance with the contract.

A large amount of work has been done in the improvement of the water-power pool specified in the contract, including the excavation of about 56,000 cubic yards of rock material, the extension of the wing-dam as required in the contract, and raising about one-half mile of the dam to an increased height of 3 to 8 feet.

This part of the work is not yet finished and a full detail report of the whole work is deferred until its final completion.

NOTE.—Work in the pool was resumed in August this year, with a very favorable stage of water, and was prosecuted advantageously until the 18th of September, when a freshet in the upper river caused a rise to nearly extreme high water here, broke the dams, flooded the work, and has given much trouble. The river is still at a high stage, continuous heavy rains have caused a fresh rise, and I fear it may be impossible to resume the work this season.

D. W. FLAGLER,
Lieutenant-Colonel of Ordnance, Commanding.

ROCK ISLAND ARSENAL, ILLINOIS,
October 8, 1884.

APPENDIX B.

Abstract of record kept at the Rock Island Bridge during the year.

PASSING NORTH.

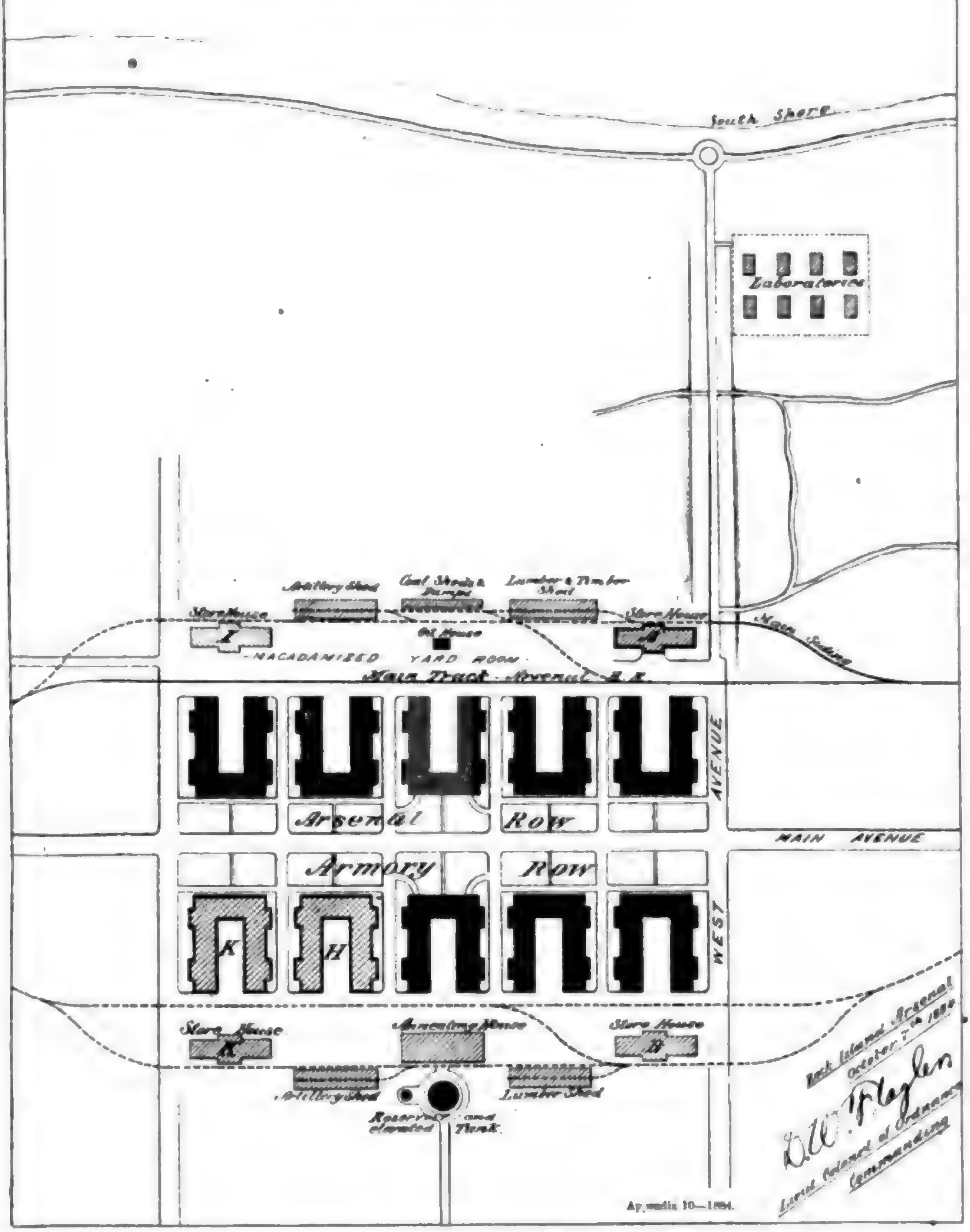
Engines with trains	6,953
Engines without trains	569
Total engines	7,522
Passenger cars	12,340
Freight cars	106,053
Foot passengers	285,406
Teams	176,287
Steamboats	1,381
Barges	74

PASSING SOUTH.

Engines with trains	7,052
Engines without trains	564
Total engines	7,616
Passenger cars	12,413
Freight cars	105,750
Foot passengers	290,205
Teams	178,560
Steamboats	1,392
Barges	75
Rafts	1,056

PLATE I.

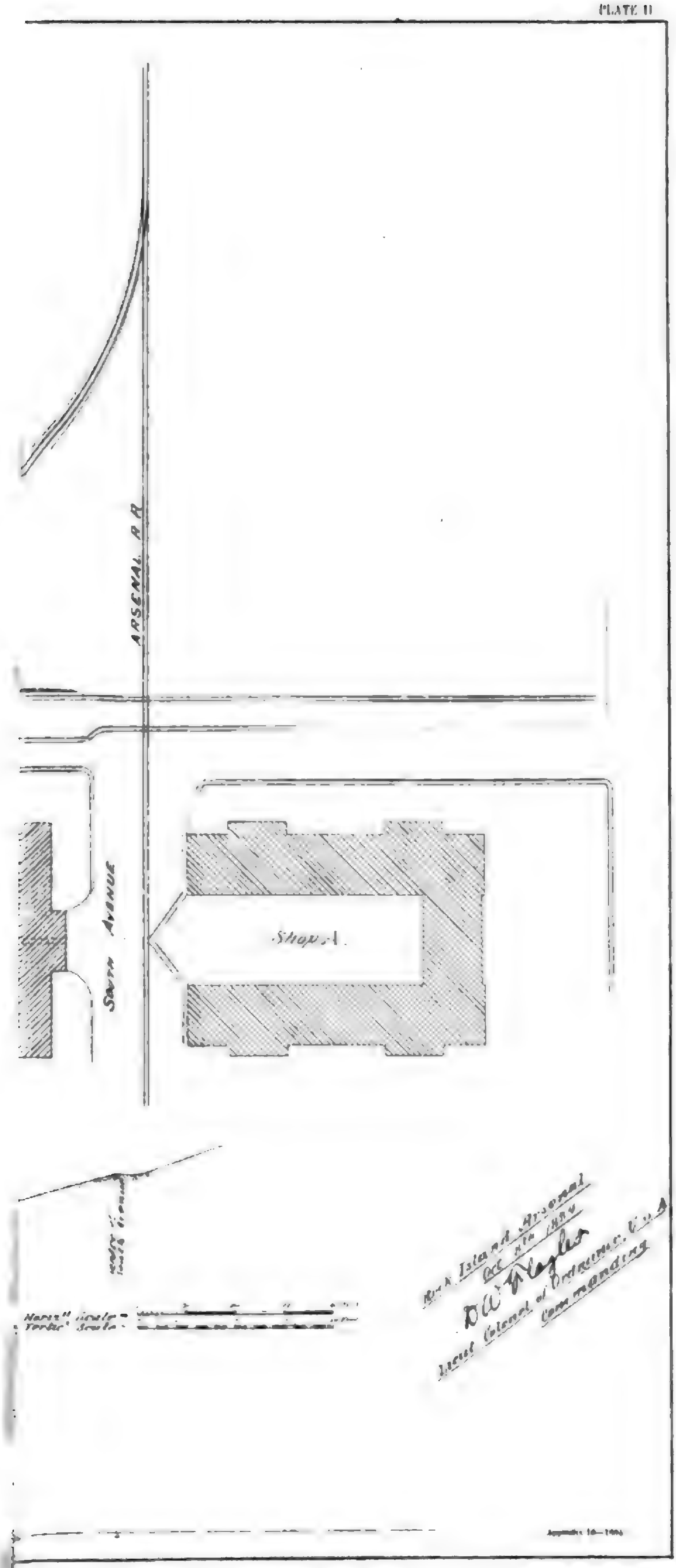
MAP OF A PORTION OF ROCK ISLAND ARSENAL



Rock Island Arsenal
October 7th 1884
D. W. Flagler
Lieut. Colonel of Ordnance
Commanding

Appendix 10—1884.

PLATE II



Appendix 10—1886

APPENDIX 11.

REPORT OF THE PRINCIPAL OPERATIONS AT THE UNITED STATES POWDER DEPOT, DOVER, N. J., DURING THE FISCAL YEAR ENDED JUNE 30, 1884

BY MAJ. J. P. FARLEY, ORDNANCE DEPARTMENT, COMMANDING.

(3 plates.)

UNITED STATES POWDER DEPOT,
August 15, 1884.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: In order to present in a consecutive manner the operations conducted at this post during the fiscal year ending June 30, 1884, it will be necessary to embrace the work done during the last two months of the previous fiscal year.

My predecessor's report closed April 21, 1883, and the following statement exhibits the amount of funds on hand at that date, the amount of building material delivered and paid for ready to be applied in the construction of magazine No. 2, and the funds received since that date. The disposition of these supplies and funds to the 30th of June, 1884, is likewise indicated in the statement:

Total received since April 21, 1883.

1883.		
Apr. 21.	Amount transferred by my predecessor	$25,561 24
	Value of material on hand for constructing magazine No. 2 (iron, cement, bricks, &c.)	12,000 00
July 1.	Amount appropriated for powder depot, available after July 1, 1883	40,000 00
	Amount appropriated for ordnance service, available after July 1, 1883	1,000 00
	Total received to June 30, 1884	78,561 24

Total expended from April 21, 1883, *to June* 30, 1884.

Amount expended for labor on magazine No. 2	$6,356 28	
Amount expended for new material on magazine No. 2	10,734 63	
Estimated value of material on hand, purchased prior to April 21, 1883, and used after that date in construction of magazine No. 2	12,000 00	
Amount expended for incidentals, magazine No. 2	4,790 26	
		$33,881 17
Amount expended for labor on magazine No. 3	5,566 11	
Amount expended for material on magazine No. 3	503 14	
Amount expended for incidentals on magazine No. 3	992 40	
		7,061 65

Amount expended for labor on guard and engine-house	$6,813 00	
Amount expended for material on guard-house	2,442 42	
Amount expended for incidentals on guard-house	1,520 00	
		$10,775 42
Amount expended for labor on stable	1,753 85	
Amount expended for material on stable	917 68	
Amount expended for incidentals on stable	435 10	
		3,106 63
Amount expended for general repairs of buildings	943 50	
Amount expended for incidentals in general repairs of buildings	155 10	
		1,098 60
Amount expended on roads, drains, grounds, &c	12,133 99	
Amount expended in incidentals on roads, drains, grounds, &c	1,994 00	
		14,127 99
1884.		
June 30. Amount available for future expenditure, and on deposit with the assistant treasurer United States at New York		8,509 78
Total accounted for		78,561 24

NOTE.—"Incidental" expenditures under each head is a pro rata distribution of miscellaneous expenses.

MAGAZINE NO. 2.

Work on this building, which has been completed during the present fiscal year, was commenced May 1, 1883, at or above the water-table. Three hundred and ninety-one thousand three hundred and thirty common bricks, 20,045 hollow bricks, and 2,195 skew-backs were used in the building, distributed as follows:

Common bricks:	
In walls	310,930
In wells	5,900
In floor arches	74,500
Hollow bricks in ceiling arches	20,045
Skew-backs in ceiling arches	2,195

Five hundred and twenty-two superficial feet stone were cut and dressed for steps, sills, &c. Two hundred and seventy-six barrels cement and 223 barrels lime were consumed in making mortar.

The structural iron, consisting of I and channel beams, tie-rods, columns, roof-trusses, &c., was furnished under contract by the Passaic Rolling-Mill Company, of Paterson, N. J.

The two fire-proof wrought-iron doors and eight pairs wrought-iron fire-proof shutters, with frames complete, were furnished under contract by the Althause Iron Company, of New York. The same company also furnished the corrugated iron roof (12,369½ square feet), with 410 feet galvanized iron gutter, 99 feet galvanized iron leader-pipe, and 406 feet galvanized iron drip-pipe, the whole being placed on the magazine by this company and painted with two coats of Prince's metallic paint.

This method of roofing was recommended by my predecessor, as well as by the Ordnance Board, and approved by the Department. Two thousand four hundred feet 1-inch diameter galvanized iron wire rope, with hemp center, and weighing 1½ pounds per foot, were used for lightning conductors. The system of protection and method of attachment is that recommended in the report of March 29, 1882, of the Board on Protection of Gunpowder Magazines from Lightning. (See Annual Report of Chief of Ordnance for 1882, pp. 527 to 530.)

For the interior wood-work of the magazine 47,865 feet of lumber, consisting of boards, scantling, and joists, were used.

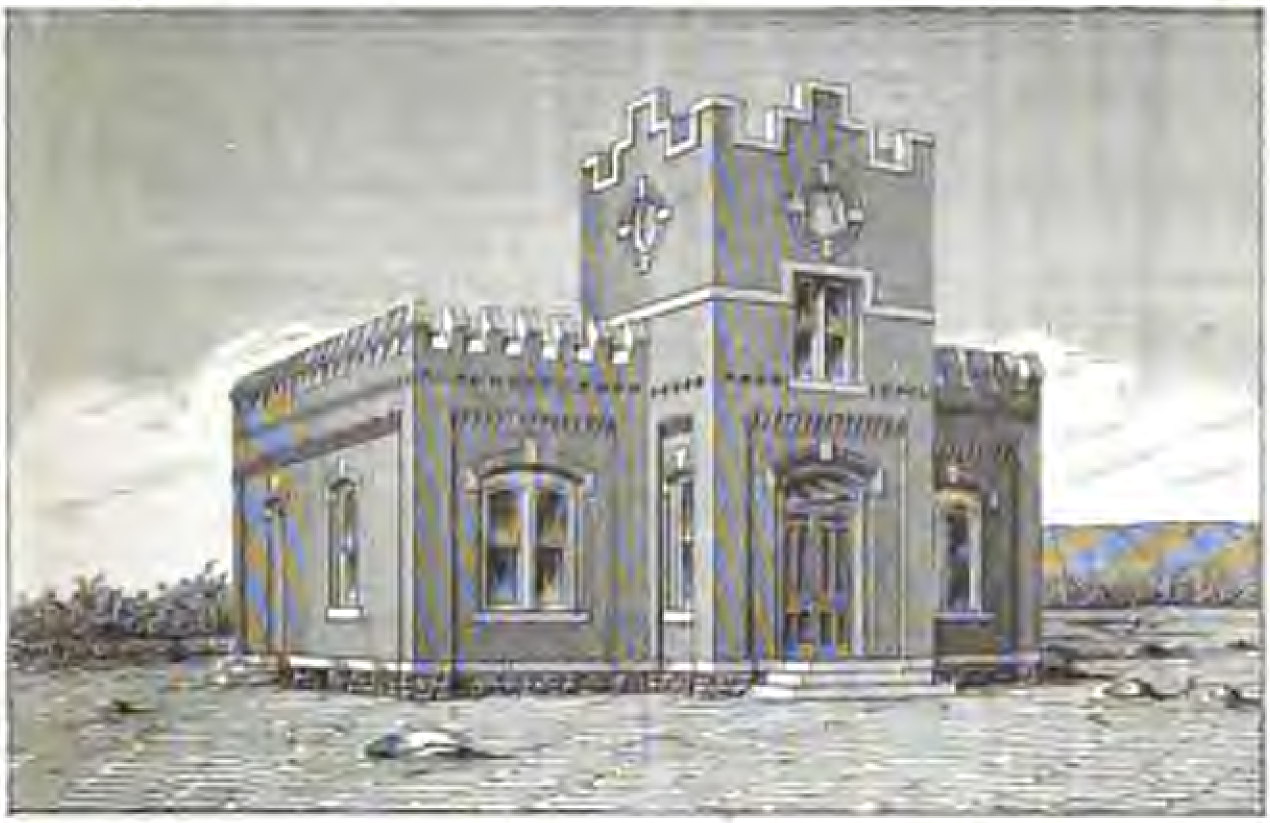
Referring to the first magazine constructed at this post my predecessor says:

> From experience so far, and from estimates of cost of different plans of construction, it is thought best to reproduce this plan in all respects except in the following minor details, viz: to have no cellar room; to reduce the thickness of the walls by one brick; to alter the construction of the iron doors and window-shutters, and in placing the buildings hereafter to incline them more towards the north and south line, to get greater benefit from the sun's rays on the west side in the winter. It is thought that these changes, together with the greater facilities which time has given us, will lessen the cost of the next magazine, notwithstanding the increase in cost of labor and material.

These proposed changes have all been realized with the completion of magazine No. 2, and its total cost has not exceeded $44,633.66, as against $50,579.99 for magazine No. 1.

With the development of our quarries, opening of roads, avenues, and improved accommodations for workmen, it is expected that the cost of magazine No. 3 will be even less than the foregoing figures.

For details and specifications relating to magazine construction at this post, see accompanying paper marked A.



GUARD AND ENGINE HOUSE.

This building, which has been completed at a total cost of $10,775, is intended to serve many useful purposes at this post.

The plans prepared and submitted by me on July 24, 1883, are on file in the War Department.

The building will ultimately be used as a post guard and engine house, and for that reason it has been located at a point near the principal gates or approaches from Dover and Mount Hope. For the time being it will serve as a general headquarters and temporary office at the powder depot, also as the steam fire-engine house.

Work on this building was commenced about the middle of June, 1883, and in its construction 3,800 cubic feet of earth were excavated to form cellar, and 2,400 cubic feet stone masonry laid in foundation walls; 4,500 cubic feet of quarried stone were hauled to site of building for subfoundation; 22,000 cubic feet of earth were removed from front of and around building for grading site; 2,061 superficial feet stone were cut and dressed for water-table, belt, window-sills, coping, battlements, and steps; 68,150 common bricks and 18,600 pressed bricks were laid in the walls, requiring 62 barrels lime and 41 barrels cement for mortar for brick and stone work. A tin roof, measuring 1,900 square feet, together with the necessary gutter and lead pipes, were put on the building, and the whole painted with two coats of metallic paint.

For better understanding of the general plan and details reference can be had to the drawings before referred to as being on file in the War Department, and to the bills of material and estimate of labor hereto appended, and marked B.

BARN AND STABLE.

This building was commenced April 21, 1884, in accordance with plans prepared and submitted by me January 12, 1884, and now on file in the War Department. It is estimated that its cost will not exceed $10,700, and that it will be ready for occupation by the first of November of the present year.

It covers a large area of ground, and will meet all the requirements of the post.

Provision is made for a hay-loft in which to store the annual crop of hay, and is so placed as to be removed from the animals for its better preservation.

A much needed store-room for agricultural tools and implements, together with carriage, harness, and feed rooms, are provided.

A large southeast court or stable yard, with open sheds for carts and wagons, is placed to good advantage, whilst adequate accommodations for the maximum number of animals are provided in the wing of the building.

For better understanding of the general plan and details reference can be had to the drawings before referred to as being on file in the War Department, and to the bills of material and estimate of labor hereto appended and marked B.

The amount of work done on the barn and stable to June 30, 1884, is as follows:

Ditch, 2 feet by 2 feet 6 inches, dug and lined with stone	lineal feet	250
Earth excavated and removed from foundation	cubic feet	3,600
Mortar masonry built in foundation	do	4,580
Stone cut for window sills	square feet	234
Stone cut for pier caps	do	162
Stone cut for belt	do	862

Ten barrels cement and 30 barrels lime were used in mixing mortar for masonry foundation; 4,580 cubic feet stone were carted from quarry, and 100,000 bricks from Port Oram to building site, to be used in its construction.

AVENUES, ROADS, AND GROUNDS.

MOUNT HOPE AVENUE.

In accordance with plans prepared and submitted by me June 23, 1883, and on file in the War Department, the work of building and grading a main avenue (on which will be located many of the accessory buildings at this post) has been rapidly advanced during the past three months. The old county road or public thoroughfare is very irregular in its course and grade, but by joining its terminal points and raising the bridge at the brook a fine avenue will be developed.

During the present fiscal year the following work has been done on this avenue: 135,600 cubic feet of earth and stone excavated and used for grading and filling; 1,896 cubic feet mortar masonry and 340 cubic feet dry masonry for bridge piers, culverts, &c., have been built.

MOUNT PLEASANT AVENUE.

In accordance with plans submitted January, 1884, and approved, this new avenue has been commenced. This, together with Mount Hope avenue, will constitute the two axes of reference in the location and construction of all new accessory buildings. The two avenues intersect at right angles at the northeast corner of the guard-house. Mount Pleasant avenue, starting at the main or Dover entrance, is to be carried to the upper end of the magazine sites—that is, to the lake or water-power dam. In time permanent workshops will be located at this point, to replace the temporary buildings now in use.

The avenue, when completed, will be 60 feet in width, with sidewalks and shade trees, for a length of 5,483 feet, being similar in all respects to Mount Hope avenue.

It is further contemplated to build a good drive-way from the terminus of Mount Pleasant avenue around the lake (and leading to the stone-quarries), a distance of two miles.

The following work has been done during the fiscal year on this avenue: 54,000 cubic feet earth excavated and used for grading and filling road-bed; 4,100 cubic feet dry masonry and 426 cubic feet mortar masonry built for bridges, culverts, and side walls.

MOUNT PLEASANT ROAD.

At the main or Dover entrance we strike the Mount Pleasant road, which leads to Dover and to the freight depot at Port Oram. It has been necessary during the past year to expend much labor on this road, and at a point 700 feet from the Union turnpike, and one and a quarter miles from the powder depot, to leave the old road and cross the ravine and stream by a short cut, thereby avoiding a steep ascent and descent over the intervening ridge.

The following work on this road has been done during the fiscal year: 162,300 cubic feet earth and stone excavated and used for filling and grading road-bed; 2,020 cubic feet mortar masonry built in bridge piers, and 20,420 cubic feet dry masonry built in side walls of road.

GROUNDS.

In breaking down, cultivating and improving the land, the following crop has been harvested:

Hay cut, stacked, and stored	tons	61
Oats (16 acres)	bushels	530
Buckwheat (10 acres)	bushels	134
Good corn	bushels	600
Soft and moldy corn	bushels	451
Value of crop, about		$1,500
Cost of labor, &c		1,000
Gain		500

Number of public animals foraged for the year:

Horses	5
Mules	4
Oxen	2

DRAINS.

Three hundred and fifty lineal feet of ditch and drain were dug, requiring the excavation of 16,300 cubic feet of earth; 6,660 cubic feet of dry masonry were built in the side walls.

RAILROAD.

Active measures have been taken during the past year to develop the intention of the Philadelphia and Reading Railroad Company, this road having acquired control of the Central Railroad of New Jersey, in the matter of constructing a branch road from the main line to the United States Powder Depot.

It appears, however, that but little dependence can be placed upon a private enterprise of this kind, where the returns will not justify the outlay; and, unfortunately for us, the reasons which induced the Central Railroad Company of New Jersey to accept the right of way through the Powder Depot tract no longer exist.

In a letter dated September 22, 1882, H. S. Little, president Central Railroad Company of New Jersey, waives all right the company may have acquired by the act of Congress approved July 31, 1882, published in General Orders No. 110, Adjutant-General's Office, of that year.

The importance and necessity of having a branch railroad from Port Oram (the junction of the Delaware, Lackawanna and Western Railroad and Central Railroad of New Jersey) to the United States Powder Depot, a distance of 3 miles, is so evident, that I am satisfied the Department will secure the necessary legislation for this purpose when the construction of this post has sufficiently far advanced.

ESTIMATE.

My annual estimate accompanies this report.

Respectfully submitted.

J. P. FARLEY,
Major of Ordnance, Commanding.

A.

DETAILS OF MAGAZINE CONSTRUCTION AT THE UNITED STATES POWDER DEPOT, NEW JERSEY.

1. APPLICATION OF EMPIRICAL FORMULÆ.
2. BILL OF IRON WITH REMARKS THEREON.
3. SPECIFICATIONS FOR GALVANIZED-IRON ROOF.
4. BILL OF LUMBER.
5. BILL OF STONE, BRICKS, LIME, AND CEMENT.
6. VERTICAL MEASUREMENTS OF MAGAZINE NO. 2.
7. HORIZONTAL MEASUREMENTS OF MAGAZINE NOS. 2 AND 3.
8. DESCRIPTION OF LIGHTNING-RODS.

Respectfully submitted.

J. P. FARLEY,
Major Ordnance, Commanding.

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1. *Application of empirical formulæ.*

(From Trautwine & Carnegie's tables.)

The weight of building and contents not to exceed 6,000 pounds per square foot, on foundation and piers.

The maximum load on floor beams, length between supports 10 feet, will not exceed 33,572 pounds, about 410 pounds per square foot, as follows:

	Pounds.
Powder in barrels (seven tiers; probably will not exceed 12,875 pounds)	28,000
Solid brick arch	4,700
Floor joist	512
Flooring	360
Total	33,572

The 12.25-inch wrought-iron floor beam.

$$(A)\ \ldots\ \left\{\begin{matrix}\text{Center breaking}\\ \text{weight}\end{matrix}\right\} = \frac{\overline{ab} \times \overline{bh}^2 \times 2500}{L} - 2\frac{fc \times fg \times 2500}{L} - \tfrac{1}{2}W \text{ (Trautwine)}$$

$L = 10$ feet
$W = 416$ pounds
$ab = 4''.79$
$bh = 12''.25$
$fc = 2''.155$
$fg = 10''.875$

(See Fig. 2, Plate II.)

$$\left\{\begin{matrix}\text{Center breaking}\\ \text{weight}\end{matrix}\right\} = \frac{4''.79 \times \overline{12.25}^2 \times 2500\,2}{10} - \frac{''.155 \times \overline{10.875}^2 \times 2500 \times 2}{10} - 208 = 52192$$

$$\begin{array}{ll}
\log\ 4.79 = .680336 & \log\ 2.155 = .333447 \\
\log\ 12.25^2 = 2.176272 & \log\ 10.875^2 = 2.072860 \\
\log\ 2500. = 3.397940 & \log\ 2500. = 3.397940 \\
\qquad\qquad\ \ 6.254548 & \log\ \ \ 2 = .301030 \\
\log 10 = 1 & \qquad\qquad\ \ 6.105277 \\
\qquad 5.254548 = 179700 & \log\ \ 10 = 1 \\
 & \qquad\qquad\ \ 5.105277 = 127400
\end{array}$$

$179700 - 127400 = 52300$
$52300 - 208 = 52192$

Center breaking weight $= 52192$
Distributed breaking weight $= 104384$
Factor of safety $= \frac{104384}{33572} = 3\frac{4}{10}$

The factor of safety is based upon a *maximum* load of powder and barrels, 28,000 pounds. The contemplated load of powder for storage of 10,000 barrels in each magazine will probably not exceed 12,875 pounds.

Deflection of 12.25-inch wrought-iron beam under maximum load.

$$\frac{\overline{10}^3 \times 33572 \text{ max. load}}{70 \times \overline{12.25} \times 37820 \text{ safe load}} = ''.13$$

Also by Trautwine—

$$\frac{.013 \times 33572 \times (10 \times 12)^3}{26000000 \times 271} = ''.107$$

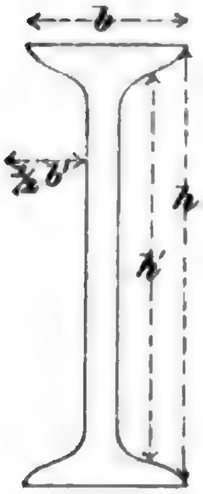
$$\begin{array}{llll}
 & & \text{Mod. elastic} & \text{Mom. inertia} \\
\log .013 & = & & 2.113943 \\
\log 33572 & = & & 4.525976 \\
\log \overline{120}^3 & = & & 6.237543 \\
 & & & 8.877462 \\
\log 26000000 & = 7.414973 & & \\
\log 271 & = 2.432969 & &
\end{array}$$

$$\frac{9.847942}{1.029520} = ''.107$$

The moment of inertia (neutral axis perpendicular to web)=271

$$\text{(C)} \quad . \;.\; . \quad \frac{bh^3}{12}-\frac{b'h'^3}{12}=\frac{4.79\times 12.25^3}{12}-\frac{(2.155)\times 2\times(10.875)^3}{12}=271$$

(See Fig. 2, Plate II.)



$$\begin{array}{lll}
\log & 4.79 & =\ .680336 \\
\log & 12.25^3 & =3.264408 \\
\hline
 & & 3.944744 \\
\log & 12 & =1.079181 \\
\hline
 & & 2.865563=733.7 \\
\log & 2.155 & =\ \ 333447 \\
\log & 10.875^3 & =3.109290 \\
\log & 2 & =\ \ 301030 \\
\hline
 & & 3.743767 \\
\log & 12 & =1.079181 \\
\hline
 & & 2.664586=461.9=\underline{271}
\end{array}$$

WOOD FLOOR JOIST.

Length between supports = 8 feet.
Load on each joist = 3836 pounds.

$$\text{Centre breaking weight}=\frac{8^2\times 4\times 450}{8}=14400 \text{ pounds.}$$

Distributed breaking weight = 2 × 14400 = 28800 pounds.

$$\text{Factor of safety}=\frac{28800}{3836}=7\tfrac{1}{2}$$

$$\text{(B).}\quad .\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\quad \text{Deflection}=\frac{(3836\times .625)\times 8^3\times .00032}{4\times 8^3}=.1918$$

$$\text{or deflection}=\frac{\text{W}\times(\text{depth in inches})^3\times .013}{\text{mod. elas.}\times\text{mom. of inertia}}=\frac{3836\times(8\times 12)^3\times .013}{1600000\times 170}=.16$$

$$\frac{4\times 8^3}{12}=\text{moment of inertia}=170$$

$$\begin{array}{lll}
 & \log 3836 = & 3,583879 \\
 & \log\ 96^3 = & 5.946813 \\
 & \log .013 = & \bar{2}.113943 \\
\hline
 & & 7.644635 \\
\log 1600000 = 6.204120 & & \\
\log 107 \qquad = \underline{2.230449} & & \\
 & & \underline{8.434569} \\
 & & \bar{1}.210066 = ''.16
\end{array}$$

Wrought-iron 10.5 *inches ceiling beam.*

Length between supports = 23'.16
W = 866 pounds
ab = 4''.5
bh = 10''.5
fc = 2''.0625
fg = 9''

See Fig. 1, Plate II.

$$\text{Center breaking weight} = \frac{4.5 \times 10.5^2 \times 2500}{23.16} - \frac{2.0625 \times 9^2 \times 2500 \times 2}{23.16}$$

$$\begin{array}{ll}
\log\ 4.5 = .653213 & \log 2.0625 = .314394 \\
\log 10.5^2 = 2.042378 & \log\ 9^2 = 1.908485 \\
\log 2500. = 3.397940 & \log\ 2500. = 3.397940 \\
\overline{6.093531} = 1240300 & \log\ 2 = .301030 \\
 & \overline{5.921849} = 835310
\end{array}$$

$$1240300 - 835310 = 404990$$

$$\frac{404990}{23.16} = 17486 = \text{center breaking weight.}$$

Distributed breaking weight = 17486 × 2 — 866 = 34102.

$$\text{Factor of safety} \frac{34102}{\underset{\text{actual load,}}{8352}} = 4 \text{ nearly.}$$

Deflection for a light 10.5 *inches beam.*

$$\text{Deflection} = \frac{.013 \times 8352 \times (23.2 \times 12)^3}{26000000 \times 173.8}$$

$$\begin{array}{rl}
\log\ 013 & = \bar{2}.113943 \\
\log\ 8352 & = 3.921790 \\
\log\ (23.2 \times 12)^3 & = 7.334007 \\
 & \overline{9.369740} \\
\log\ 26000000 = 7.414973 & \\
\log\ 173.8 = 2.240050 & 9.655025 \\
 & \bar{1}.714715 = .5184
\end{array}$$

With a light arch of hollow brick (6″ instead of 10″ brick) the weight per square foot reduces to 32 pounds × 23¼ × 8 = 5952 pounds : about .48 safe load.

$$\text{The deflection then} = \frac{.013 \times 5952 \times (23.25 \times 12)^3}{26000000 \times 173.8}$$

$$\begin{array}{rl}
\log\ .013 & = \bar{2}.113943 \\
\log\ 5952 & = 3.774663 \\
\log\ 279^3 & = 7.336812 \\
 & \overline{9.225418} \\
\log.\ 26000000 \times 173.8 & = 9.655025 \\
 & \bar{1}.570393 = .''3718 = \frac{1}{697} \text{ span nearly.}
\end{array}$$

Cast-iron columns.

Gordon's formula for cast-iron columns gives (see Fig. 1, Plate II).

$$\text{Crushing weight} = \frac{\text{metal area} \times 80000}{1 + \dfrac{(\text{length in inches})^2}{3200 \times \dfrac{(\text{diam.})^2}{8}}} = \frac{12518 \times 80000}{1 + \dfrac{(164.4)^2}{3200 \times \dfrac{7^2}{2}}} = 420950$$

Actual weight on each column = 9133 pounds.

Factor of safety $= \frac{420950}{9133} = 47$ nearly.

$$\log\ (164.4)^2 = 4.431804$$
$$\log\ 3200 \times \frac{7^2}{8} = 19600 = 4.292256$$
$$.139548 = 1.379$$
$$+1.$$
$$2.379$$

$$\frac{12518 \times 80000}{2.379}$$

$$\log\ 12518 = 1.097533$$
$$\log\ 80000 = 4.903090$$
$$6.000623$$
$$\log\ 2.379 = 376394$$
$$5.624229 = 420950$$

On page 224, Trautwine, is a table of strength of cast-iron pillars, showing for 6 inches diameter, ¾ inch thick, and 14 feet long (near enough) a breaking load of 10.4 tons = 20,800 pounds.

The ends of the columns are fixed, and with the load, 9,133 pounds, the factor of safety is 22.7. This factor of safety covers defects in quality of material and in workmanship. For a small casting of size easy to work and ocupying an unimportant position, factor of safety = 3 would be ample; but considering the danger that would result from weakness in any one column, and the difficulty of centering and of drawing so long a core from a thin column, as well as of detecting defects that may exist, the factor of safety should not be *less* than 22.7. The 7-inch column with a factor of safety of 47, however, appears in better proportion for the large area supported.

ARCH TIE-RODS.

The lateral thrust of ceiling arch per lineal foot $= t \cos a = \frac{Ws}{2h} = 308$ pounds.

W = ½ weight of lineal foot of arch = 128 pounds
s = ½ span of arch = 4′
h = rise of arch = ′.83
a = = 11° 45′

$$t = \frac{W}{2 \sin a} = \frac{128}{2 \times .2036418} = 316$$
$$t \cos a = \frac{128 \times 4}{2 \times '.83} = 308$$

308 pounds × 47 = 14476 pounds.

With 6 rods, each rod carries

$$\frac{14476}{6} = 2412 \text{ pounds}$$

Tenacity ¾″ rod = 50000 × .441 = 22050.

Factor of safety $= \frac{22050}{2412} = 9.14$.

With 9 rods (heretofore used) factor of safety $= \frac{22050}{1608.7} = 13.7$.

The tie-rods for ceiling arches secure rigidity of beams while the several arches are being placed, and since the thrusts neutralize each other when the arches are all in, clamps might be used and taken off when all the arches are set.

The arches, however, cannot be trusted to neutralize each other when set in a magazine, nor is the end wall weighty enough to withstand the thrust of the end arch should the rods be omitted.

(See section on A–B and A′–B′, Plate II.)

Without tie-rods or abutments the moment of instability with reference to the upper plane of water-table and due to the thrust of the end arch = 308 × 47 × 15 = 217140 = (moment of instability).

The *negative* weight of air space, window space, and panels is offset by positive weight of gable end and roof. Hence the

L. A.

Moment of stability = 100 × 47 × 15 × 2 × 1 = 141000.

This assumes a solid 2-foot wall, 15 feet high and 47 feet long, and shows insecurity without rods or abutments, $\frac{141000}{217140} = \frac{65}{100}$

ABUTMENTS.

With an abutment 3 feet on base, 2 feet thick, gradually tapering to a height of 11 feet, and placed at intervals of 12 feet on the wall, we have section on A–B, Plate II.

C ⊙, center of gravity of semi-arch, whose weight is 128 pounds—lever arm E-D = 1′ 11″.

A, center of horizontal pressure—lever arm O-E = 6¼″.

Area of sectional wall, 15′ × 2 = 30′.

Weight per lineal foot of wall = 100 × 30 = 3000.

H ⊙ = center of gravity of sectional gravity of sectional wall, excluding gable roof, windows, &c.

I ◬ = center of gravity of buttress.

G ◬ = center of gravity of buttress and section wall.

Buttress 2 feet thick, 12 feet apart.

Weight of 12 feet length of wall and arch (128 × 3000) × 12 = 37536.

Weight of 12 feet length of wall and arch and buttress = 39736.

Weight centered at G ◬ = 39736.

Lever arm M N = 3.75.

Moment of stability = 39736 × 3.75 = 149010.

Horizontal thrust at ○ = (308 × 12) = 3696.

Lever arm O N = 15′.

Moment of instability = 55340.

$$M = \frac{149010}{55340} = 2.7 \text{ (nearly)}$$

Tie-rods serve better purpose than abutments.

ROOF TRUSS.

(See Fig. 1, Plate III.)

Weight per square foot of truss, corrugated iron, wind and snow, is taken at 41430 pounds.

Slope of roof, about 30°.

Total length of roof, 205′; width of span, 47′.9.

Distance between each truss, 10′ (except at ends).

Total number of trusses, 19.

Total mean length or middle length of rafter, 28′.82.

Weight on each span between struts = 7′.2 × 10′ × 41.43 pounds = 3000 pounds.

Total weight = 24000 pounds on each truss.

$$2\,W = \text{weight of rafter and load} = 24000 \text{ pounds}$$

$$W \text{ at } C = 12000 \text{ pounds}$$

$$\tfrac{1}{2}\,W \text{ at } A \text{ and } A' = 6000 \text{ pounds}$$

$$l = AC = 28'.82$$

$$t = \frac{W}{2 \sin 30^\circ} = 12000$$

$$t \sin 30^\circ = 6000$$

$$t = \frac{6{,}000}{\sin 30^\circ} = 12000$$

$$t \cos 30^\circ = \text{thrust on middle tie } GG = 12000 \times 866 = 10392$$

10400 pounds (nearly)

This would also equal the thrust on the whole tie, if no struts were employed.
Actual strength of tied rod GG′ (1¼″) by experiment = 61360.

$$M = \frac{61360}{10400} = 6 \text{ (nearly)}$$

The perpendicular and parallel components of the 3000 pounds weight on each section of rafter between struts = 3000 cos 30° and 3000 cos 60°, respectively, = 2600 pounds and 1500 pounds.

The strut BG carries 5200 pounds and transfers this *extra* strain to rod FG = (10400 + 5200) pounds, and 5200 pounds to rod EH.

The rod FG, or secondary end tie, being double, *each* rod is under strain

$$\frac{10400 + 5200}{2} = \frac{15600}{2} = 7800$$

The tenacity of these 1″ rods = 39270 pounds:

$$M = \frac{39270}{7800} = 5 \text{ (nearly)}$$

The strut DF carries 2600 pounds, and transfers this extra strain to rod FA = (10400 + 5200 + 2600) pounds, and 2600 pounds to rod FB.

The rod FA, or "end tie," being double, each rod is under strain

$$\frac{10400+5200+2600}{2} = \frac{18200}{2} = 9100$$

The tenacity of these 1⅛″ rods = 49701 pounds:

$$M = \frac{49701}{9100} = 5 \text{ (nearly)}$$

The rod HC is a single "peak tie," and carries 5200 + 2600 = 7800 pounds.
Tensile strength (1″) = 39270

$$M = \frac{39270}{7800} = 5 \text{ (nearly)}$$

The secondary strut ties BH and BF each receive a strain of 2600 pounds.
Tenacity of ⅝″ rod = 15340.

$$M = \frac{15340}{2600} = 6 \text{ (nearly)}$$

RAFTER.

Rafter AC is a strut as well as beam. (See Formula A.)

$$\text{Center breaking weight} = \frac{3 \times 6^2 \times 2500}{7.24} - 2\left(\frac{1\tfrac{3}{8} \times \overline{5.09}^2 \times 2500}{7.24}\right)$$

$$\begin{array}{lrr@{\qquad\qquad}lrr}
\log & 3 = & .477121 & \log & 2\times1\tfrac{3}{8} = 2.75 = & .439333 \\
\log & 6^2 = & 1.556302 & \log & 5.09^2 & = 1.413436 \\
\log & 2500 = & 3.597940 & \log & 2500 & = 3.397940 \\
\cline{3-3}\cline{6-6}
 & & 5.431363 & & & 5.250709 \\
\log & 7.24 = & .859739 & \log & 7.24 & .859739 \\
\cline{3-3}\cline{6-6}
 & & 4.571624 = 37292 & & & 4.390970 = 24602
\end{array}$$

$$37292 - 24602 = 12690 \times 2 = 25380$$

Actual load 2600.

$$M = \frac{25380}{2600} = 9 \text{ (nearly)}$$

$$\text{Deflection} = \frac{(7.24)^2}{70 \times 6} = .125 \text{ with safe load}$$

$$\text{or, } .125 \times \frac{2600}{8646} = .037 \text{ with actual load}$$

$$\text{or, } \frac{.013 \times 2600 \times (7.24 \times 12)^3}{26000000 \times \underset{\text{Moment of inertia.}}{23.5}} = ''.036.$$

$$\begin{array}{lrlr}
\log & .013 = & & 2.113943 \\
\log & 2600 = & & 3.414973 \\
\log & 7.24 = & & .859739 \\
\log & 12 = & & 1.079181 \\
\log & 7.24 = & & .859739 \\
\log & 12 = & & 1.079181 \\
\log & 7.24 = & & .859739 \\
\log & 12 = & & 1.079181 \\
\hline
 & & & 7.345676 \\
\log & 26000000 = & 7.414973 & \\
\log & 23.5 = & 1.371068 & 8.786041 \\
\hline
 & & & 2.559635 = .03627
\end{array}$$

The moment of inertia, 23.7, comes from

$$\frac{bh^3}{12} - \frac{b'h'^3}{12} = \frac{3 \times 6^3}{12} - \frac{2.75 \times (5.09)^3}{12} = 23.7$$

$$\frac{3 \times 6^3}{12} = 54 \quad \log \; 2.75 = .439333$$

$$\begin{array}{rr}
\log (5.09)^3 = & 2.120154 \\
\hline
 & 2.559487 \\
\log \; 12 = & 1.079181 \\
\hline
 & 1.480306 = 30221
\end{array}$$

$$54 - 30.221 = 23.779$$

(See previous formula, C.)

AS A STRUT.

The first quarter section C E is under compression of the weight at the peak 12000 pounds plus the several parallel (to rafter) components of the strain on tie-rods due to the struts BG, EH, and BF.

$12000 + (x + y + z) = 12000 + 4500 = 16500$

The next quarter section $16500 + 1500 = 18000$

The next quarter section $18000 + 1500 = 19500$

The next quarter section $19500 + 1500 = 21000$

CARNEGIE'S TABLES.

$\frac{l}{r} = 2.9$; $l = 7'.24$, length between struts; r = radius gyration neutral axis perpendicular to web.

$$r = \sqrt{\frac{\text{moment of inertia}}{\text{area}}} = \sqrt{\frac{23.5}{4.1}}; \; r = \sqrt{5.73} \qquad r = 2.46 \qquad \frac{l}{r} = \frac{7.24}{2.46} = 2.9$$

Carnegie page 79, gives (for 2.9) pin (37310 — 170) = 37140; 37140 pounds = resistance per square inch of area; 37140 × 4.1 = 152270 = total resistance.

Allow for strain as beam and take total resistance at 132270.

$$M = \frac{132270}{21000} = 6.3$$

With no allowance $M = \frac{152274}{21000} = 7.25$

The center breaking weight of 4-inch purlins (see Formula A)

$$\frac{2\tfrac{1}{4} \times 4^2 \times 2500}{10} - \frac{2(1\tfrac{3}{64} \times (3.45)^2 \times 2500}{10} = 2770$$

$$\frac{2\tfrac{1}{4} \times 4^2 \times 2500}{10} = 9000$$

$$\begin{array}{ll} \log 2\,(1\tfrac{3}{64}) = & .320924 \\ \log 3.45^2 & = 1.075638 \\ \log 2500 & = 3.397940 \\ \hline & \,4.794502 \\ \log 10 & = 1 \\ \hline & \,3.794502 = 6230 \end{array}$$

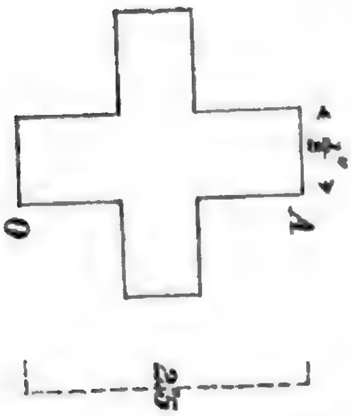
$$9000 - 6230 = 2770$$

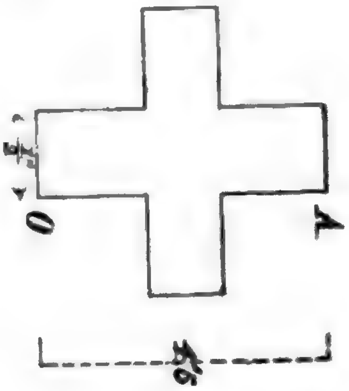
Load on purlins distributed will not exceed

$$10 \times 2.5 \times 41 = 1025; \quad M = \frac{2 \times 2770}{1025} = 5.4$$

COMPRESSION ON STRUTS.

$$OA = \sqrt{20.25} = 4.5$$





Main strut B G

$$\begin{array}{l} \text{Area} \\ \dfrac{4.25 \times 80000}{10000} = 72282 \\ \left(\dfrac{3200 \times 20.25}{24}\right) \end{array}$$

$$\begin{array}{lll} \log.\ 4.25 = & .628389 & \\ \log.\ 80000 = & \underline{4.903090} & \\ & 5.531479 = 340000 & \\ \log.\ 10000 = 4 & & \\ \log.\ \ 24 = & \underline{1.380211} & \\ & 5.380211 & \\ \log.\ 3200 = & & 3.505150 \\ \log.\ 20.25 = & & \underline{1.306425} \\ & 4.811575 & \\ & \overline{}568636 = 3.704 + 1 = 4.704 & \end{array}$$

$$\frac{340000}{4.704} = 72282$$

$$M = \frac{72282}{5200} = 13$$

$$OA = \sqrt{6.25} = 2''.5$$

In like manner for struts DF and EH we have:

$$\frac{\frac{2.25 \times 80000}{2500}}{1+\left(\frac{3200 \times 6.25}{24}\right)}$$

$$M=\frac{45000}{2600}=17$$

The strength of the wrought-iron bolts used is shown in the following columns.

The Factor of Safety is calculated upon the supposition that the transverse strain is applied at a distance of 1 inch from the surface entered, the bolts being supported at but one end.

$$\frac{D^3 \times 2500}{\frac{1}{12}} \times .589 \div 4 = \text{transverse strength.}$$

Bolts, wrought-iron.

(Strain one inch from surface entered.)

Diameter.	Transverse strength.	Tenacity.	Actual strain.	Factor of safety.*
Inches.				
2	35340	157080	†$\frac{15600}{2}$	4.5
2	35340	157080	†$\frac{18000}{2}$	4.
1¾	23676	120265	7800	3.
2	35340	157080	†$\frac{18000}{2}$	4.
1¾	23676	120265	7800	3.
1	4416	39270	2600	1.6
1	4416	39270	2600	1.6
¾	1864	22090	‡932	2.
¾	1864	22090	‡932	2.
½	552	9818	‡276	2.
½	552	9818	‡276	2.
⅝	1080	15340	‡540	2.
¾	1864	22090	‡932	2.
¾	1864	22090	‡932	2.
¾	1864	22090	‡932	2.
⅜	232	5528	‡116	2.
⅜	232	5528	‡116	2.
⅝	1080	15340	‡540	2.
2	35340	15340	21000	1.7

*When the strain is distributed the actual factor of safety will be double the factor in last column.

†Double rod.

‡Assumed strain.

2. *Bill of iron for a magazine building.*

(From the post records.)

I BEAMS.

Depth.	Flange.	Web.	Pounds per yard.	No.	Length.		Use.	Total weight.
Inches.	*Inches.*	*Inches.*			′	″		*Pounds.*
12.25	4.79	.48	125	48	24	0	Floor beams	48,000
10.5	4.5	.375	105	48	24	9.	Ceiling beams	41,580
6.	3.	.25	40	38	*28 †28	11.09 7.59	Rafters	14,640
4.	2.25	.15625	18	186	20	.55	Roof purlins	22,394
4.	2.25	.15625	18	24	20	9.	do	2,988
4.	2.25	.15625	18	20	10	9.	do	1,290

* Top. † Bottom.

[BEAMS.

					′		
12.25	3.	.375	87.5	4	24	End floor beams	2,800
10.5	2.5	.3125	70.	4	24	End ceiling beams	2,140

2. *Bill of iron for a magazine building*—Continued.

FLAT BARS.

Size.	Pounds per yard.	No.	Length.		Use.	Total weight.
″ ″			′	″		*Pounds.*
⅝ by 3	18¾	48	2	0	Column clamps	600
⅝ by 2	12½	104	1	4	Beam anchors	577
¾ by 2½	18¾	8		10½	Channel-beam clamps	42
½ by 3	15	100		8	Bent for column stay angles	333
¼ by 7	17½	1	13	0	Cut to patterns for 38 peak splices	76
¼ by 3	7½	836		2¾	Purlin clamps, cut to patterns	480
¼ by 1¼	3⅛	209		4½	To connect purlin ends	156

ROUND BARS.

(1. For roof-truss ties, with ends of flat iron.)

Diameter.	Pounds per yard.	No.	Length.		Use.	Total weight.
″			′	″		*Pounds.*
1⅛	10	76	8	6.96	End ties	2,174
1	8	76	8	6.96	Intermediate ties	1,739
1	8	38	16	7.54	Peak ties	1,685
1¼	12½	19	17	6.16	Middle ties, with right and left nut	1,350
⅝	3 1/10	76	8	6.21	Secondary ties	669
⅞	6	25	7	11.65	Column stays	398

(2. With nuts and heads as Stays.)

			′	″		
1	8	138	8	3	Floor-beam tie-rods	3,036
1	8	12	7	9½	End floor-beam tie-rods	250
¾	4.5	200	8	3	Ceiling-beam tie-rods	2,475
⅞	6	36	10	2½	Roof-truss stays	786
⅞	6	4	10	2½	End roof-truss stays (with foot)	82

ANGLES.

Size.	Pounds per yard.	No.	Length.		Use.	Total weight.
Inches.			′	″		*Pounds.*
2+2 by ¼ (60)	9⅜	2	20	.65	Peak stays (with foot)	125
2+2 by ¼ (60)	9⅜	8	20	.55	......do	501

TWO ATTIC WINDOWS.

(Frame, cast iron.)

	No.	Size.	Total weight.
			Pounds.
Plates	2	⅜″, 47¾″ diameter	125
Angles	4	1″+1″×5/32″, 22¼″ long	7.5
Angles	8	1″+1″×3/32, 21⅜ long	14.26
Channel	2	1″ deep, ⅜″ flange, 3/16″ web, 43″ long	7
Channel	4	1″ deep ⅜″ flange, 3/16″ web, 21″ long	7
Hinges	4	19″×2″×⅜″	15
Thumb screw	2	½″ diameter, 8″ long over all	2

2. *Bill of iron for a magazine building*—Continued.

WROUGHT-IRON BOLTS.

Diameter.	Length.	Number.	Place.	Weight.
Inches.	*Inches.*			*Pounds.*
¼	10	112	Anchor pins	20
2	9	38	Base main strut	575
2	8½	38	Base first strut	558
1¾	6½	38	Base third strut	330
2	10	38	Shoe	608
1¾	9	38	Peak tie	394
1	9¼	38	Top of main strut	112
1	7½	76	Top of first and third struts	188
¾	2¾	38	Peak splice	43
¾	3⅛	50	Column stay	61
½	2½	56	Peak stay	21
½	10	4	End peak stay	3
⅝	10	4	End rafter stay	5
⅝	3	208	Beam anchor	166
⅝	3¼	16	Channel beam clamp	14
⅝	3½	96	Column clamps	84
⅜	1½	1,672	Purlin clamp to rafter, beveled heads	95
⅜	1½	416	Purlin clamp to end, straight heads	47
½	35½	44	Purlin bolts, end section	130
*2	7⅛	76	Shoe dowels	660
½	2½	16	Grating bolts	4

* Dowel.

WROUGHT-IRON WASHERS.

Bolt diameter.		Number.	Weight.
Inches.			*Pounds.*
Seven-eighths	Round	76	13
Three-fourths	.....do	320	50
One-half	1 inch square, ⅛ to ½ inch bevel	56	4

CASTINGS.

	No.	Size.	Weight.
			Pounds.
Attic window frame	2	Diameter, 49½″; d. 4½″	150
Columns	24	Diameter, 7″; L 13 ft. 8.4″ × th ⅝″	12,864
Column caps	24	h 4″ × 14″ × W 9″	1,272
Rafter shoes	38	h 10⅞″ × 12½″ × W 12″	2,460
Main struts	38	L 8′ 5.96″ × 4½″ + × ½″ th	5,548
Secondary struts	76	L 4′ 5.48″ × 2½″ + × ½″ th	3,192
Shoe washers	76	L 7″ × W 5⅞″ × 1½″ th	836
Strut and peak washers	304	L 4″ × W 5⅞″ × 1¼″ th	1,824
Ventilator doors	16	L 18½″ × W 3⅜″ × ½″ th	80
Ventilator door frames	16	L 19″ × W 4″ × 4½″ th	400
Ventilator frames	8	L 18½″ × W 14″ × 1½″ th	288
Ventilator gratings	8	L 18½″ × W 12″ × 1″ th	200

RECAPITULATION.

	Number.	Weight.
		Pounds.
I beams	364	130,892
[beams	8	4,940
Flat bars	1,515	2,265
Round bars	810	8,015
Round bars	390	6,579
Angle at peak	10	626
Attic windows	2	177
Bolts	3,400	4,094
Washers	452	67
Castings	630	29,114
Total	....	186,769

All the weights here given are estimated.

TWO DOOR-FRAMES.

Inside measurement, 4 feet wide; 8 feet maximum, 7 feet 8 inches minimum height.
Side angle three-eighths inch iron, 3 by 4 inches; 7 feet 8 inches height.
Iron door-frames three-eighth inch thick by 4 inches wide.

TWO DOORS.

2-inch iron, one-half-inch thick, covered with sheet-iron.

EIGHT WINDOW-FRAMES.

Inside measurement, 4 feet wide; 7 feet maximum, 6 feet 8 inches minimum height.
Side angle three-eighths inch irons, 3 by 4 inches; 6 feet 8 inches height.

SIXTEEN SHUTTERS, TWO FOR EACH WINDOW.

Frame 2 by ½ inch iron covered outside with sheet iron; inside with corrugated iron; two bolts and one on bar each window.

GALVANIZED-IRON ROOF.

12,369¼ square feet galvanized iron, corrugated, No. 20 gauge, roofing.
410 feet galvanized iron, No. 20 gauge, gutter.
99 feet galvanized iron, No. 20 gauge, leader-pipe.
406 feet galvanized iron, No. 20 gauge, drip-pipe.

LIGHTNING-ROD ATTACHMENTS.

	Number.	Weight.
		Pounds.
Cast-iron pipes and caps	2	1,980
Clamps for ridge roll (wrought-iron)	5	18
Gas-pipe:		
Crosses or double tees	15	29
Tees	16	
Gilded points ... sets	5	42
Wrought-iron straps with tap bolts and staples:		
For attic window	2	239
For left jamb of door	2	
For windows	16	

The lightning-rod attachments are made to pattern from drawings.

REMARKS ON THE FOREGOING BILL OF IRON.

All of the iron is of the best quality usually manufactured by leading iron manufacturers for building purposes, and according to shapes and dimensions shown and given in drawings and bill of iron furnished contractors.

The wrought iron stands a tensile strain of 50,000 pounds (see record of tests) per square inch, and stretches 15 per centum of its original length before breaking. It does not undergo appreciable permanent elongation under a less strain than 25,000 pounds per square inch, and shows the characteristics of good iron when bent cold and broken.

The beams have the strength and stiffness laid down and claimed for them in the tables published by the leading iron manufacturers and rolling mills of the United States. They are straight, out of wind, the planes of the flanges parallel to each other and perpendicular to the web, and are free from flaws, blisters, ragged and torn edges or other blemishes and evidences of bad iron. The dimensions agree in all respects with those given in the drawings.

All bolt holes are accurately made at the proper points and of the proper sizes, and the beams are delivered completed as to all finishing work necessary to their fitting in their proper places and to their being properly joined with the other component parts of the building.

The tie rods, tie bolts, rafter stays, angle and bar iron are without defective welds or flaws, straight, accurate in dimensions, delivered finished ready to be put in the building, bolt heads drilled, screw threads cut, heads formed as shown in the drawings, so as to insure accurate fitting and joining with the other component parts of the building.

The castings are free from flaws, blow holes, or other defects. The columns and their caps are straight and accurate in dimensions; the ends and faces planed or turned perfectly true, level and at right-angles with the length of the columns. The thickness of the columns is uniform, and they fit their caps accurately and have full and perfect bearing at the ends.

All of the iron finished according to specifications with the parts and pieces thereof is subject to inspection and test before acceptance. It is then cleaned and primed with one coat of paint before delivery.

Record of tests by tensile stress of iron rolled by the Passaic Rolling Mill Company.

[Stevens' Institute of Technology.]

Original mark No. 5. Laboratory No. 2151. Material: Wrought iron, 1¼ inches, unwelded. Dimensions:* Length, 2.1 inches; diameter, .795 inch.			Original mark No. 4. Laboratory No. 2149. Material: Wrought iron, 1 inch, unwelded. Dimensions:† Length, 2.06 inches; diameter, .795 inch.		
Loads.	Elongation.	Sets.	Loads.	Elongation.	Sets.
	Inches.	*Inches.*		*Inches.*	*Inches.*
8, 000	.0022	....	8, 000	.0027	....
9, 000	.0029	.0003	9, 000	.0034	.0004
10, 000	.003	....	10, 000	.0036	....
11, 000	.0031	....	11, 000	.0037	....
12, 000	.0039	....	12, 000	.0039	....
12, 500	.0039	....	12, 500	.0045	....
13, 000	.0043	.0012	13, 000	.0047	.0010
13, 250	.0048	....	13, 250	.005	....
13, 500	.005	....	13, 500	.0051	....
13, 750	.0052	....	13, 750	.0053	....
14, 000	.0069	....	14, 000	.0055	....
14, 250	.0087	.0042	14, 250	.0058	.0020
14, 500	.0091	....	14, 500	.0059	....
14, 750	.0092	....	14, 750	.0062	....
15, 000	.0097	.0055	15, 000	.0065	.0020
15, 250	.0099	....	15, 250	.0067	....
15, 500	.0118	....	15, 500	.0071	....
15, 750	.0127	....	15, 750	.0074	....
16, 000	.0154	....	16, 000	.0078	....
16, 250	.0199	.0185	16, 250	.0081	....
16, 500	.0245	....	16, 500	.0083	....
17, 000	.0278	....	17, 000	.0086	....
18, 000	.0321	....	18, 000	.0165	....
19, 000	.0408	.0350	19, 000	.0363	.0302

* Final dimensions: Length, 2.74 inches; diameter, .6 inch; reduction of area, 43 per cent.

† Final dimensions: Length, 2.68 inches; diameter, .618 inch; reduction of area, 40 per cent.

Broke at.......................pounds..	26, 625	Broke at.......................pounds..	28, 700
Breaking load per square inch:		Breaking load per square inch:	
Original section....................	53, 649	Original section....................	57, 832
Fractional section..................	94, 166	Fractional section..................	95, 679
Elastic limit:		Elastic limit:	
Actual..............................	13, 750	Actual..............................	14, 000
Per square inch original section ..	27, 706	Per square inch original section..	28, 209
Elongation, actual = .64 ....per cent..	32	Elongation, actual = .62 ...per cent..	30

R. H. THURSTON,
Director.

Tests of iron for magazine building.

[Record of tests by tension of irons made by Passaic Rolling Mill Company. Stevens' Institute of Technology. Material, wrought iron. Investigation by tensile strength.]

Name.	Laboratory No.	Original mark.	Dimensions.		Stress, ultimate.	Breaking load per square inch.		Extension.	
			Length L, L'.	Diameter, H, H'		Original section, T.	Fractional section, T'.	Actual.	Ratio to original length.
Inches.			*In.*	*In.*					*Per ct.*
⅝ welded	2146	1	1.6	.625	16,000	52,118	69,961	.26	16½
1 welded	2148	2	2.1	.795	28,300	57,024	85,089	.56	27
1¼ welded	2150	6	2.06	.795	26,500	53,397	67,309	.32	15

R. H. THURSTON,
Director.

Record of tests by tensile strength of irons made by Passaic Rolling Mill Company. Stevens' Institute of Technology. Original mark, No. 3. Material, wrought iron. Laboratory No. 2147. Dimensions: Length, 2.12 inches; diameter, .388 inch.]

Loads.	Elongation.	Sets.	
1,000	.002	....	Broke, 6,740.
1,250	.009	....	Breaking load per square inch, 57,002.
1,500	.016	....	Breaking load, fractional section, 102,042.
1,750	.021	....	Elastic limit, actual, 2,750.
2,000	.029	.004	Elastic limit, per square inch, 23,257.
2,250	.036	....	Elongation, per cent., 20.
2,500	.04	....	Reduction area, per cent., 45.
2,750	.044	....	Final dimensions: Length, 2.64 inches; diameter, .29.
3,000	.05	.015	

R. H. THURSTON,
Director.

3. *Corrugated-iron roof for magazine.*

Four inches purlin fastened on upper surface of rafter by wrought-iron shoes clasping the lower flange of the purlin.

Eleven purlins on each hip 33¾ inches apart. Purlins joined together by 4-inch iron strips 1 by one-fourth inch.

The rafters and purlins are covered by best bloom galvanized corrugated iron sheets, No. 20 wire gauge, fastened to the purlins by galvanized iron strips, riveted to the *top* corrugations on the under side, and carried around and under the purlins to the *top* of the opposite corrugations. This prevents leakage through the rivet holes. The sheets are 3 feet wide by 7 feet 3 inches long and are fastened together by tinned rivets.

The holes are punched *uniform* and the rivets fit accurately, the old hand-punch being abandoned in favor of a new method, which insures a much closer fit of the rivet.

The sheets lap 1½ inches, and the old plan of simply painting the lap after riveting has been abandoned in favor of the use of canvas strips 1½ inches wide, dipped in white lead and oil, which are inserted between the lapped surface of the iron before riveting. The buckle raised by punching is in this manner perfectly filled up, and both a water and air tight joint is secured. When the saturation of the canvas hardens, it practically cements the surfaces of contact.

On the ends of the building galvanized iron gable cornices are placed and securely fastened to the roof covering. On the ridge and eaves galvanized iron flashings are employed in part corrugated to avoid a seam at this part of the roof. The roof is painted with one coat of Prince's metallic paint on the outside.

The gutter is of the same grade of iron as the roof, No. 20 gauge, and partially supported by the cornice and iron hooks at intervals of 2 feet, the hooks being fast to the rafters. (See Fig. 3, Plate III.)

A, B, C, D is a wrought-iron strap to hold the eaves-trough of five-sixteenth inch iron, 2 inches wide. It is carried up and bolted to the lower purlin with two one-fourth inch bolts at the point D. The eaves-trough is formed to fit strap and extends above the angle at the roof 4 inches. The first or lower sheet on roof is 13 inches wide, 5 inches plain, 8 inches corrugated, bent over angle at C, and laps 1¼ inches in the eaves-trough; all other sheets overlap 1½ inches and are 3 feet wide and 7 feet 2 inches long. Two rods five-eighths inch round iron, 34 inches long, connect the lowest pair of purlins (between rafters) in order to more accurately hold the eaves-trough. The distance between purlins is 33¾ inches from center to center.

The straps FF′ are employed to connect the roof covering with the purlins, passing from top of corrugation on the one side to the top of corrugation on the opposite side of purlins.

4. *Bill of lumber for a magazine building.*

Chestnut floor beams, 3 by 8 inches by 17 feet	pieces	460
White-pine, first clear, window jambs, 3 by 4 inches by 13 feet	do	28
White-pine pickings for furring strips, 2 by 4 inches by 16 feet	do	132
White-pine pickings for furring strips, 2 by 4 inches by 12 feet	do	74
Clear-faced tongued and grooved Georgia pine flooring 1¼ by 4¼ inches	feet	17,500
Clear-faced white pine ceiling, 1 by 3 inches by 13 feet	do	8,500
First clear white pine, 2 inches by 16 feet	do	500
First clear white pine, 1 inch by 16 feet	do	200
Spruce for scaffolding, 2 by 10 inches by 16 feet	do	3,000
Hemlock for centers, 1 by 6 inches by 12 feet	do	3,100
Centers, &c., for turning arches:		
White-pine pickings, 2 by 12 inches by 16 feet	pieces	64
White-pine pickings, 1 by 12 inches by 16 feet	do	500
Hemlock, 2 by 4 inches by 16 feet	do	50
Hemlock, 3 by 1 inch by 16 feet	do	16

5. *Bill of masonry for magazine.*

FOUNDATION.

Mortar, masonry, granite for walls and piers	cubic feet	13,134
Cement for same	barrels	212
Lime for same	do	42

WATER-TABLE.

Cut stone, granite, bush-hammered	superficial feet	509
Cut stone, granite, bed joints and pitch faced	do	3,666

ABOVE WATER-TABLE.

Common bricks, in walls		310,930
Common bricks, in wells		5,900
Common bricks, in floor arches		74,500
Hollow bricks in upper arches		20,045
Skew-backs in upper arches		2,195
Cut and dressed stone, granite for steps, sills, &c	superficial feet	522
Cement for above	barrels	276
Lime for above	do	223

6. *Vertical measurements of magazine No. 2.*

LEVELS FROM TOP OF WATER-TABLES.

		Ft.	In.
Ground level	below	— 1	8
Bottom of stone foundation	below	— 6	0
Floor	above	+ 1	10
Lower side ceiling beams		+13	9
Top side ceiling beams		+14	7¼
Bottom of lower ventilator, inside building		+ 3	4
Bottom of top ventilator, inside building		+11	3
Bottom of all ventilators, outside building (ventilator frame outside 4 by 19 inches)		+ 1	2
Base of panel (10 courses of brick)		+ 2	2
Top of panel (57 courses of brick)		+12	7
Top space above panel to cornice (65 courses of brick)		+14	4

	Ft.	In.
Top cornice (70 courses of brick)	+15	6
Top side-wall or pier (70 courses of brick)	+15	6
Top of window-sill	+ 4	10
Top of window	+11	6
Base of shoe	+15	6
Center of shoe-bolt	+16	0
Middle rafter joint at peak	+30	7½
Top rafter joint at peak	+30	10⅝
Center attic window	+23	1½

7. *Horizontal measurements of magazines Nos. 2 and 3.*

Inside measurement of floor or ceiling, 46 feet 11 inches by 198 feet 11 inches.
Distance between iron columns, center to center, 8 feet.
Distance from end of building to center of first column, 7 feet 5½ inches.
Distance from side of building to center of column, 23 feet 5½ inches.
Outside measurement of brick-work, 51 feet 2 inches by 203 feet 2 inches.

END WALLS OF MAGAZINE.

Stone foundation 62 inches wide to a height of 2 feet 1 inch from base; at that point with an offset of 12 inches on the inside and 20 inches on the outside of foundation wall, wall 30 inches wide for a height of 3 feet 1 inch to water-table; water-table (height 8 inches), resting on this wall, width 32 inches, chamfered 1 inch by 2 inches.

SIDE WALLS OF MAGAZINE.

Stone foundation 56 inches wide to a height of 2 feet from base; at that point with an offset of 12 inches on the inside and 20 inches on the outside of foundation, wall 24 inches wide to water-table; water-table, resting on this wall, 26 inches wide; upper brick walls, end and side, 22½ inches thick in pier, including air space; wall in panels, 18½ inches thick.

8. *Remarks relative to lightning-rods.*

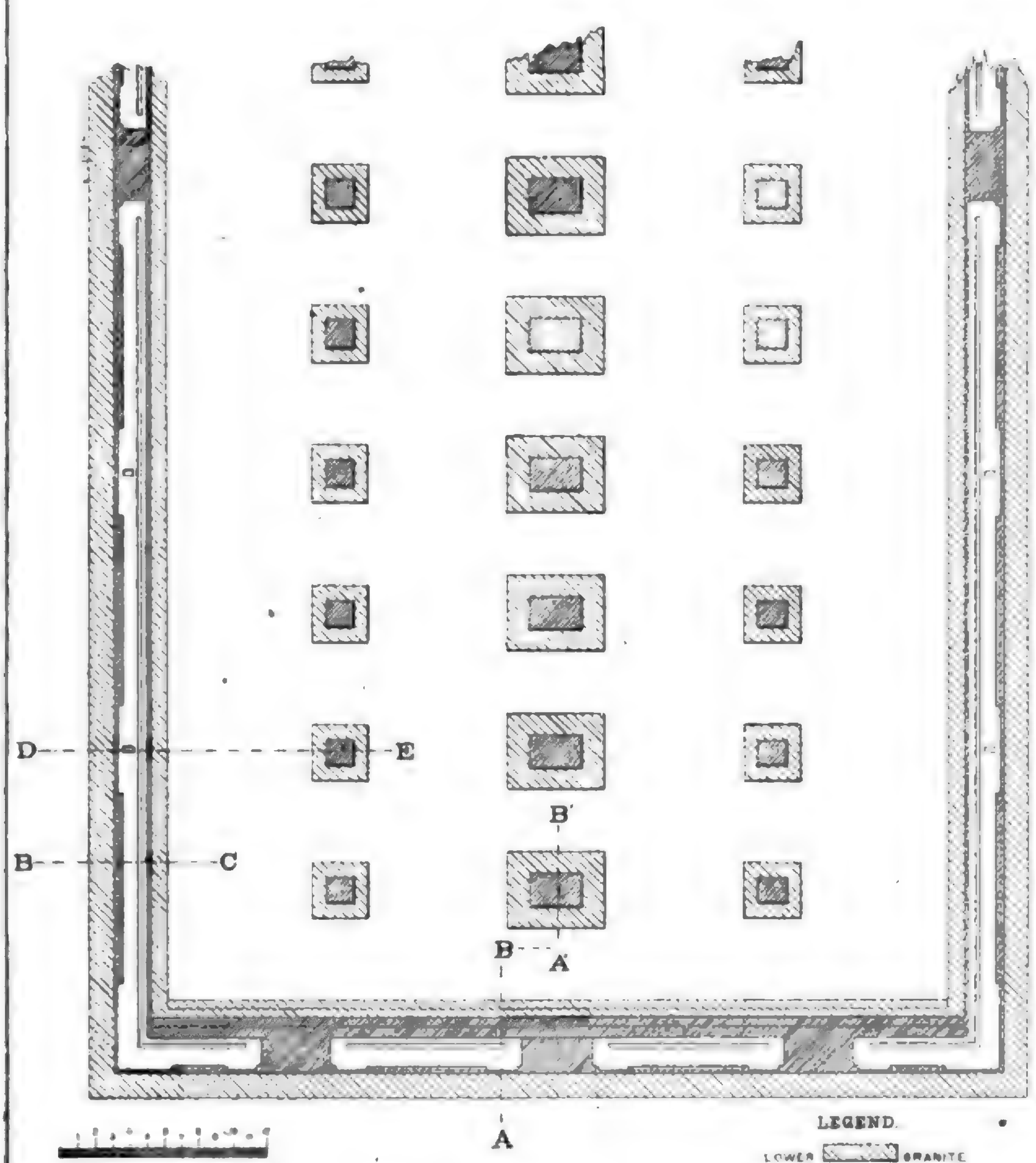
The lightning rods are placed on the magazine in the manner recommended by the "Board on Protection of Gunpowder Magazines from Lightning," nearly as follows:

The magazines are provided with five conductors of 1 inch galvanized iron wire rope, well painted, each conductor running continuously from the ridge down opposite faces of the building and connected by a soldered joint with a cast-iron water-pipe 10 feet long, 1 foot in diameter, inserted in a wet well; the central and extreme conductors passing behind the water-spouts. The curvature at the eaves is such that the length of the curved portion does not exceed one and a half times the distance between the initial and terminal points of the curve. The upper terminal of each conductor is a 1 inch galvanized iron rod with a beveled and gilded extremity, surrounded at 1 foot from the end by an iron collar screwed and soldered to it, holding six equidistant pointed and gilded iron wires 6 inches long. The length of the terminal rods does not exceed 6 feet.

The vertical portions of the wire rope are connected by a horizontal rope of the same kind and size above ground.

The holdfasts are of iron and allow free movements to the rope in expansion and contraction. The doors and shutters are connected with the conductors. (For further details see Chief of Ordnance's Report for 1882, p. 527 to 530.)

PLATE I.



LEGEND.

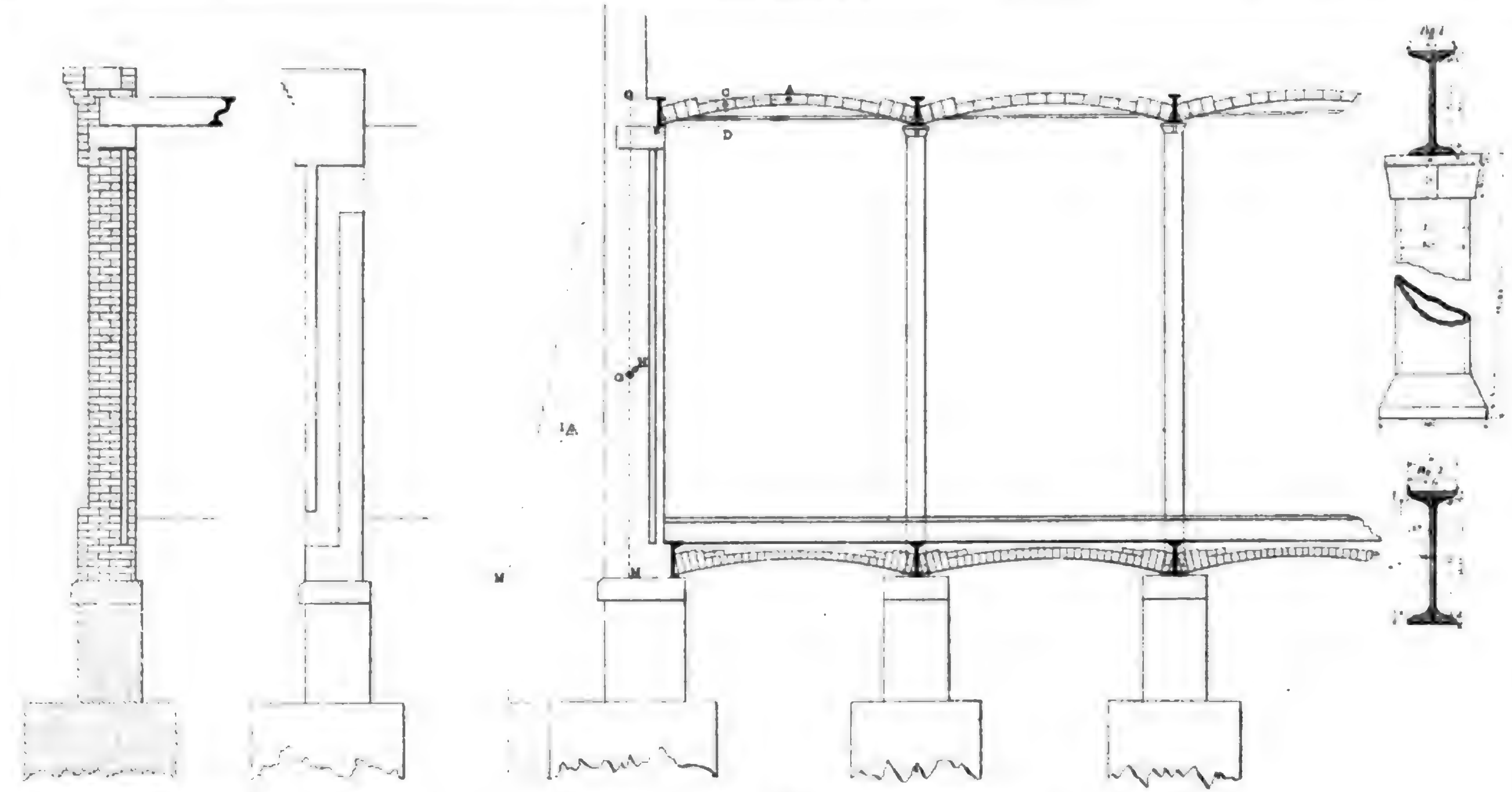
LOWER ▨ GRANITE
☐ BRICK
UPPER ▩ GRANITE

MAGAZINE

PLAN of FOUNDATION and SECTION of WALL

Appendix 11—[illegible]

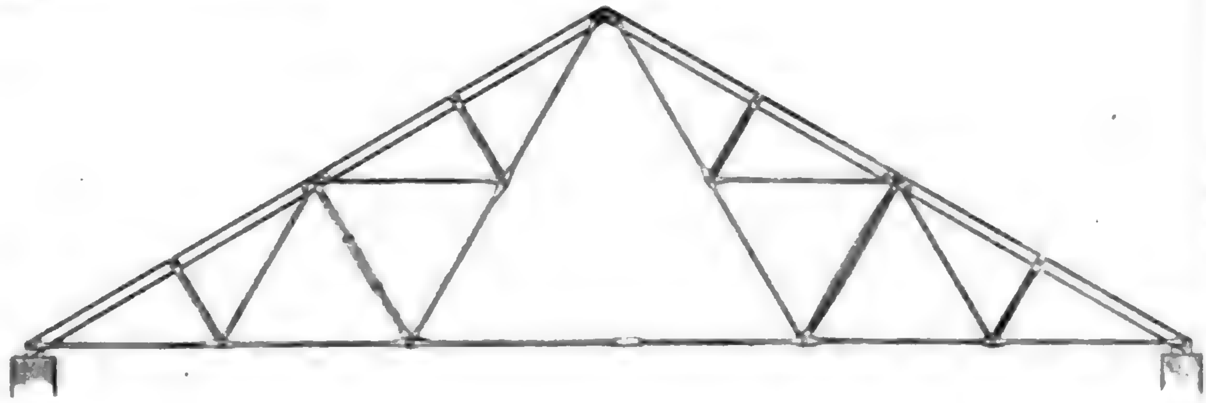
PLATE II.



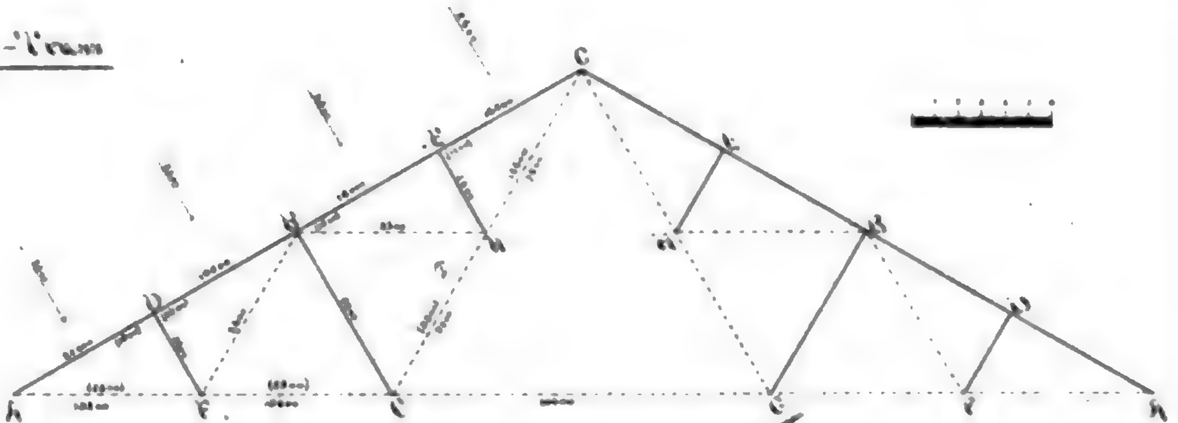
SECTION on BC SECTION on DE SECTION on AB and A'B'

MAGAZINE

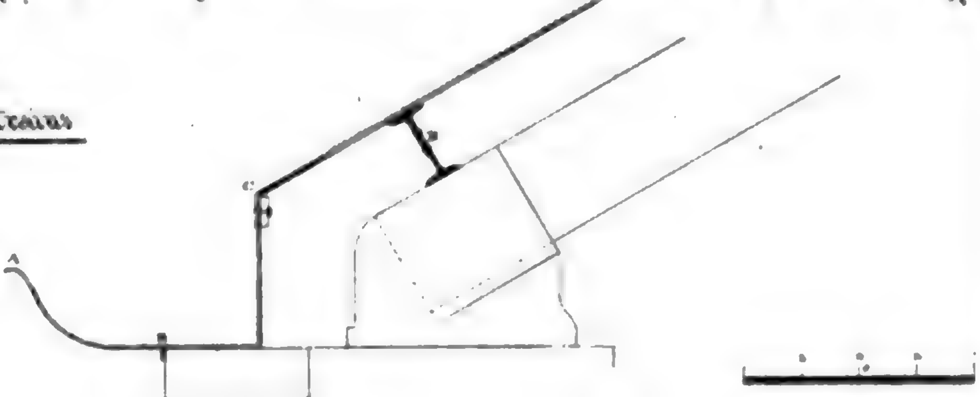
A F End Ties double [illegible] each [illegible]
F G 2nd " " [illegible]
G G Mid Tie single [illegible]
G H 2nd Peak Tie " [illegible]
H C Peak Tie [illegible]
E H and D ? 2nd Strut Ties [illegible]
A C as Strut (Carnegie's 6" light I joists [illegible])
A C " Beam (Phoenix 6" [illegible])
B G Strut [illegible] long beams [illegible]
D E and E H Strut [illegible] long beams [illegible]
Defl. of Beam



Roof-Truss



Roof-Sketch of Strains



Iron Roof and Gutter

Appendix 11—1886.

APPENDIX 12.

DESCRIPTION OF THE ROD BAYONET AND ATTACHMENT, AND FRONT AND REAR SIGHT, FOR THE SPRINGFIELD RIFLE, MODEL 1884.

BY LIEUT. COL. A. R. BUFFINGTON, ORDNANCE DEPARTMENT.

(1 plate.)

ROD BAYONET AND ATTACHMENTS.

NOMENCLATURE.

Fig. 1 represents rod bayonet and attachments on the rifle.

Rod bayonet (A). Parts: *Round blade; shoulders* (2) for locking spring; *creases* for thumb and fingers; *point grooves* 3 (I); *stem* (not showing in Fig.) size of ordinary rammer with *screw-thread* for a head, which is carried with screw driver and headless shell extractor in the butt of the stock.

Rod bayonet stud (B). Brazed to underside of barrel. Parts: *Front projection* (C); *rear projection* (D) and serving as stock tip; *bedding groove* for locking spring; *base and locking spring screw and front sight cover pin holes.* Front sight cover pin.

Locking spring (E). One catch only shown. Parts: *Base-blades; rod catches; pin and screw holes.*

Locking spring pin.

Locking spring screw.

Locking spring button (F). Parts: *Body* with *bayonet groove; thumb and finger projections* 2 (H), *creases* for thumb and fingers; *inclines* for pressing down locking spring; *pivot hole and counter sink; locking spring screw hole.* Pivot stud (under the rod, not shown) riveted to spring. Parts: *Body; head.*

MANIPULATION.

To *fix bayonet:* Place the rifle in position prescribed for "fix bayonet" with the old triangular bayonet, barrel opposite rod bayonet stud resting in palm of left hand, thumb and fingers (thumb above on the left, fingers below on the right) resting on the *creases* of locking spring button projections, thumb and forefingers of right hand clasping rod bayonet at the *creases* above the stud. Press on the projections of locking spring button *to force each as far as it will go towards the rod,* then spring the bayonet upward out of fastening, relaxing the pressure of the left hand thumb and fingers on the button projections while drawing the rod with the right hand and the rod will be caught automatically at the proper place, fixing it.

To *unfix bayonet:* Position of rifle and hands as before. After releasing the rod as above, push it downward, relaxing pressure of left hand thumb and fingers and the rod will be caught automatically in position of unfixed bayonet.

REAR SIGHT.

NOMENCLATURE.

Fig. 2 represents rear sight complete on the rifle.

Fixed base (A). Parts: *Body* with *bed* for movable base; *barrel groove; base screw holes* (2); *windage screw; seat; windage point lines.*

Windage screw and heads (*a*).

Base screws (2).

Movable base (B). Parts: *Body* with *reinforce; joint lugs* (2) *and pin holes; spring mortise; under cut spring slot; pivot hole; windage female screw threads; windage point arrow.*

Joint pin.

Base spring. Parts: *Body; beveled edges; blade; pivot hole.*

Sight leaf (C). Parts: *Body* with *joint projection; elevating pinion projection; slide drift mortise; V-shaped grooves for slide; graduations and figures for elevations.*

Elevating pinion and head (D).

Elevating pinion washer spring (E).

Slide (F). Parts: *Body* with *V-shaped sides; pinion rachet; apertures* (2) *for open sight*, lower one for elevations from 200 to 1,400 yards, inclusive; upper one for 1,500 to 2,000 yards inclusive; *aperture sight hole* for 200 to 1,400 yards inclusive; *graduation, lines, and figures* for elevation 1,500 to 2,000 yards inclusive; *buckhorns and open sight notch* (2) for "point blank" to 100 yards range, leaf down.

MANIPULATION.

Leaf raised and lowered in any position of movable base, as the present service sight leaf.

Elevation for range. To 100 yards leaf and slide down through the buckhorn open sight notch. For greater than 100 yards raise the leaf, and with the right thumb and forefinger turn the pinion head (D) upward until arrow of lower open sight notch or arrow of aperture hole, whichever be used, is opposite lines *under* the figures of desired range for all ranges to and including 1,400 yards; for greater ranges to and including 2,000 yards, which can be obtained only through the upper open sight notch, the arrow on the upper left hand side of leaf must be made, by movement of slide, to coincide with graduation lines *under* the figures of elevation on the left of the slide. As the slide, in moving upward, moves in the "slide drift mortise" of the leaf, which mortise has the inclination to the *left* (rifling being to the right) of the drift curve—practically a right line—it follows that correction for drift is thus secured automatically, requiring no thought or adjustment of the marksman for any range.*

Correction for windage is secured by the movable base (turning about the front base screw as a center, carrying the leaf and base spring with it) and windage screw (*a*), which, with the right forefinger and thumb, turn to the front for a wind from the right and to the rear for a wind from the left. The arrow head in rear, on the center line of movable base, and the windage point lines on the fixed base, record the movement.

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* Lieut. W. C. Brown, First United States Cavalry, proposed that drift lines or curves be marked on the leaf of the rear sight, model '79, so that adjustment could be made for drift; on this basis, for which credit is due to him, the automatic arrangement was devised.

FRONT SIGHT AND COVER.

NOMENCLATURE.

Front sight (2). Parts: *Steel cylindrical pin*, carried in a thimble inclosed by front sight cover.

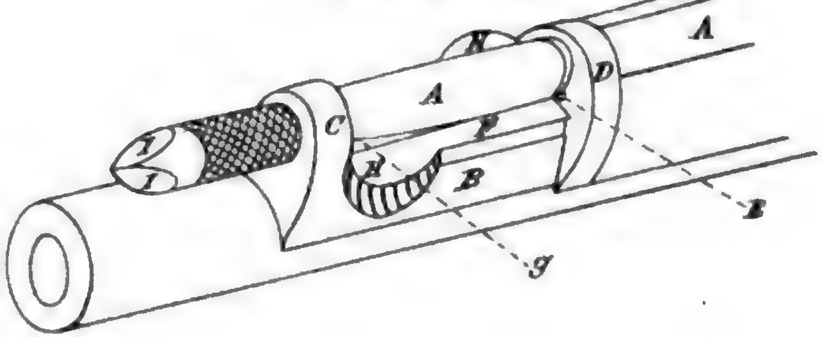
Front sight cover (D). Parts: *Body* with *barrel and sight holes; thimble recess and screw hole and bayonet stud and pin cuts.*

Thimble (E).

ROD BAYONET AND FRONT AND REAR SIGHTS

FOR SPRINGFIELD RIFLE, MODEL 1884.

Fig. 1.



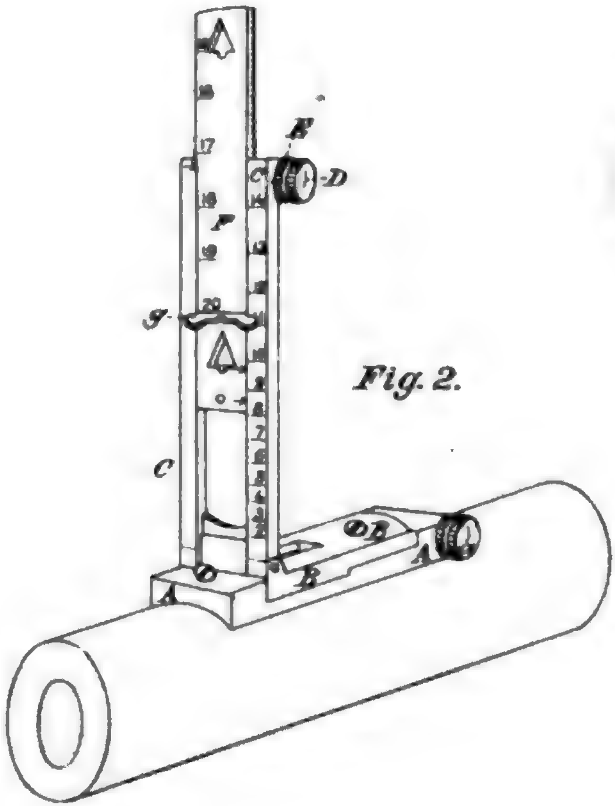
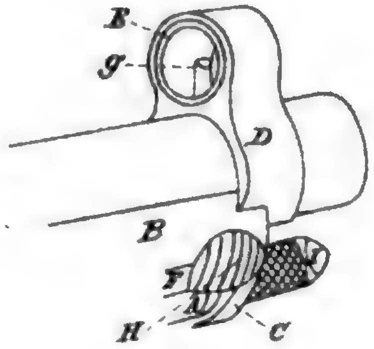


Fig. 2.

Fig. 3.



Appendix 12—1884.

APPENDIX 13.

REPORT OF ARTILLERY PRACTICE AT THE NARROWS, NEW YORK HARBOR.

BY COL. JOHN HAMILTON, FIFTH ARTILLERY.

(3 plates.)

The practice was with the 20 and 15 inch Rodman smooth-bores and 4½-inch siege-rifle. The lateness of the season, the lack of a suitable anchorage for the target, and the withdrawal of the steam-launch Thayer prevented the continuance of the firing so as to include the 100, 200, and 300 pounder Parrot rifles and the 8-inch converted rifles, all mounted at Fort Wadsworth, New York Harbor.

The details of the firing are shown in Tables I, II, and III. Considering the class of guns used in the first case (smooth-bores), the results are fairly good.

20-INCH RODMAN SMOOTH-BORE.

This piece had been fired but a very few times and the details of record were incomplete. Having broken a portion of its carriage at the close of the firing season of 1882, it had been repaired by the Ordnance Department. It was intimated that the carriage could then resist any strain of recoil with the charges to be used. I believe that this would have been the case but for unforeseen complications which brought the strains upon the carriage in an unusual manner. The details of the first round are shown in Table I. The injury was due to the fact that the chains by which the carriage was pulled "from battery" had not been unhooked, and the carriage, in recoiling over these, was raised, so that two auxiliary eye-bolts attached to the gun-carriage struck and raised the rear buffer-plate of the chassis. The damage was repaired by the Ordnance Department, and the next round was fired with reduced charge of powder (150 pounds) and an increased amount of oil (45 gallons) in the hydraulic buffer. The gun recoiled the full length of chassis, struck the rubber buffers of chassis, and sprang forward from these 2 inches. Upon the advice of Mr. Sinclair (Ordnance Department) it was concluded to fill the buffer cylinder *completely*, preparatory to again firing.

It was also considered desirable to measure the velocities of the gun. Maj. George W. McKee, Ordnance Department, United States Army, acting president of the Ordnance Board in the absence of Col. T. G. Baylor, caused instruments, material, and employés of the department to be sent from Sandy Hook twice. Unfortunately the weather proved unfavorable on both occasions. Colonel Baylor, upon his return, acceded to a request for an effort to be made a third time. Again a storm prevented the arrival of the ordnance boat from Sandy Hook. This terminated our efforts in that direction, the season being too far advanced.

The buffer was full when the piston-rod was broken in the firing of 1882, the resistance to recoil having been probably too great. Although the openings in the piston-head had been increased, some hesitancy was felt to fill the cylinder completely, and thus raise the resistance to a maximum.

Our thanks are due to the Ordnance Department for its readiness to assist us in our work and to furnish us many of the instruments and facilities required for it. Reference will be made hereafter to some of the details of these.

15-INCH RODMAN SMOOTH-BORE.

These were fired with charges of 60, 70, and 80 pounds of mammoth powder. The last-named charge did not appear to be too great either for the gun or carriage, and gave so much better results that its use was continued. The pneumatic buffers appeared to suffice for the absorption of the recoil. The carriage ran "in battery," however, and an automatic device (such as Mr. Sinclair's) for holding the carriage "from battery" after recoil might be advantageously applied on carriages of muzzle-loading guns provided with the pneumatic buffers.

Two volleys of four guns each were fired by electricity. Reference will be made to this hereafter. The target was struck by one volley, the shot clustering well.

As a make-shift, these guns may do fairly good work at ranges not exceeding 3,000 yards, if fired with 130-pound charge of hexagonal powder, as proposed, and in volleys of not less than eight guns, so that it may chance that two or more shot strike the enemy simultaneously.

4½-INCH SIEGE RIFLES.

These guns were fired only twice. At the first day's firing the target was struck in the bull's-eye. At the second, the target was blown adrift by a storm of from 40 to 50 miles. The pieces were therefore sighted at points on the Quarantine Islands, without endeavoring to allow for wind and drift, in order to obtain data as to both drift and wind deflections.

The probable drift of the Hotchkiss solid shot used (old pattern), with a charge of 3¼ pounds of mortar powder, for a range of 2,526 yards, is 8.7 yards; for 3,5 0 yards it is 22 yards. The data from which these are obtained are somewhat doubtful, contain unavoidable elements of uncertainty, and further observations to verify are desirable.

POINTING GUNS, ETC.

As the telescopic sights were not completed in time for use during the present firing, the service sights were used, and the guns pointed directly. The deflection was then given by means of pointing-boards and a pointer attached to a rear traverse-wheel of the chassis. The pointing-boards were graduated into divisions of 3′ 27″, which gives a value of .001 of the range in deflection. A sketch of the boards is attached. (Fig. 1 of Plate I.)

In order to train the eyes of cannoneers to appreciation of distances at the target and to insure perfect accuracy of pointing, etc., the following circular was published:

ARTILLERY PRACTICE CIRCULAR.

1. Elevations will not be given until just before firing.
2. The gun will first be sighted direct upon the bulls-eye, and the captain in charge of the gun will let as many of his non-commissioned officers and intelligent privates as time will permit to verify the pointing. The correction for wind-deflection will then be made, and the same men will be given an opportunity to see, by sighting, how far the line has been thrown from the bulls-eye. This of course would be the practical deflection.
3. The officer in charge of the gun will verify all pointing.
4. The elevations will be given just before firing by the chief of piece, under the immediate superintendence of the officer.
5. The gunner will adjust the electric primers on the wire and in the vent.
6. The chief of piece will dust the rail to determine recoil, and will manipulate the exploding apparatus.
7. After the first fire the captain may call on any of the men to do the initial pointing. (To be verified as in the first fire.)

In every instance the deflection allowance given for the opening fire of each day's practice brought the shot close to the line. The change of both the direction and force of the wind were closely followed. This was the more notable from the fact that at times the velocity was considerable and variable. Changes in deflection allowance of as much as 30 yards between consecutive rounds, and, in one instance, of 23 yards, after the first pointing, before firing, gave good results.

ELECTRICAL FIRING APPLIANCES.

EXPLODERS.

The guns were fired by means of the Laflin & Rand "magneto-exploders No. 3," purchased by authority received from the Chief of Ordnance, and an experimental exploder loaned to us for trial by the Laflin & Rand Company. Both worked satisfactorily. The experimental exploder was essentially a small dynamo machine, the armature of which was revolved rapidly by a spring and clock-work. It was necessary to wind up the clock-work for each time of firing. A key being pressed, a detent was released, and the armature was made to revolve rapidly. As the movement of the firing-key was continued [and when the current generated was at its maximum] it was shunted into the firing circuit. The instrument was more compact than the other form of machine, weighing 15 pounds less, and being only 5½ by 5 by 3⅝ inches in size, or about one-fifth the dimensions of the other. In its present form it is more liable to get out of order than No. 3 machine, but requires less practice to use it with certainty when in order.

CONDUCTING WIRES.

Three kinds of double conductors, cables, were used in the firing. Of these, two coils (Nos. 1 and 2) were given to me for experiment by Mr. C. A. Hotchkiss, general agent of the Day Kerite Cable Company, and No. 3 was made for our work, the order and purchase of same having been authorized by the Chief of Ordnance.

The No. 1 coil consists of two conductors, each a No. 18 B. W. G. copper wire insulated to six thirty-seconds of an inch, laid up with two cords of juting for rounding and protection, all being finally covered with tarred taping.

It has been in use for two firing seasons, has been kept in a damp casemate without particular care, has been exposed both to hot and cold weather, and appears to be as good as when received. It is very light and useful for many purposes, particularly where it is desired to fire only a single gun. It is not, however, as flexible and strong as the No. 3 cable.

No. 2 cable.—Each conductor is made of seven strands of No. 6 B. W. G. copper wire, insulated to thirteen thirty-seconds of an inch, laid up with cords of juting, and wrapped with two layers of tape.

This coil was designed to give an extremely low resistance—a matter of importance where a large number of guns are to be fired in volleys and the current available for ignition of the primers is limited. This cable, although somewhat cumbersome, is not too much so for the purpose designed, as it is to be used in permanent works. The resistance of the round circuit (equivalent to a single length of 300 yards) is only 0.36 ohm, leaving thus a wide margin for faults in primers, &c.

No. 3 cable.—This wire was designed with a view of securing the resistance due to a single No. 14 copper wire, with increased flexibility and strength. It was, therefore, made of six No. 21 B. W. G. copper wires, on a No. 20 B. W. G. steel core, which last was introduced to secure additional strength. The insulation covering was of seven thirty-seconds inch Kerite; the two conductors were held together and covered with two layers of braided and tarred sail-threads, to give ample protection to the insulation from such rough usage as it is liable to meet with in actual service. Our limited experience with this indicates that it will do all that can be required or expected, and it is in every way serviceable.

ELECTRICAL PRIMERS.

The electrical primers furnished (Frankford Arsenal of 1883) have thus far been more satisfactory than any others which I have seen used, issued by the department.

There has not been a single failure to ignite in those tried. In no case has there been a failure to ignite the cartridge and discharge the piece, although twice this was the 20-inch Rodman smooth-bore, where the distance from the primer to the cartridge was 20 inches.

It is particularly important to have reliable primers of *uniform resistance* and *sensitiveness* for volley firing. The importance of this manner of delivering fire upon any enemy cannot be overestimated It is desirable to make permanent arrangements of wires and attachments upon gun-carriages, so that any or all guns of a given battery may be connected, and so that the fire of a single gun of the series, owing to the greater sensitiveness of its primer, or the failure of one or more primers, need not prevent the fire of other guns of the series. Some appliances to accomplish the foregoing have been made, but not yet tested.

It is proposed to complete these and arrange the six 100-pound Parrotts in the barbette battery of Fort Wadsworth, so as to test them.

For volley firing at movable targets a voltaic firing battery would be better than the exploders described, because this may be arranged so that the guns may either be fired instantly upon the touch of a key, or it may still be arranged so as to fire at the expiration of a definite period after the firing-key is touched.

When, as will eventually happen, guns are worked by dynamo-electrical engines, such separate firing appliances will not be required.

In view of the large masses of modern guns and carriages and the great speed of modern vessels, it is obvious that other than manual powder will be required to manipulate the guns with sufficient facility. Three means are available: all are, however, dependent upon a central source of steam-power. The three are steam, compressed air, and electricity. The first two demand long pipes which must necessarily be exposed, and if broken cannot be readily and quickly repaired. The other, electricity, conveyed by cables, appears more practicable, as the cables can be easily and quickly replaced. Besides this, a large reserve of power may be stored up in secondary batteries, providing for the accident to the steam-engine operating the dynamos. The motors to be used at the gun are relatively small and easily replaced. A motor giving 8 horse-power has been made weighing only 350 pounds. The maximum power required will not exceed 4 horse-power.

Hydraulic machinery is obviously essentially as objectionable as either steam or compressed air. It is possible that the latter may be used by having charged reservoirs sent to the guns from a central source and attached to the motor.

In all cases the machinery should be of such character as to enable the person sighting to make the requisite movement rapidly by a touch of the finger.

TARGETS.

It has caused much difficulty to anchor our target securely with the facilities available. The wind and tide would cause the target to drag its anchor very frequently. An attempt to plant a secure anchorage for mooring the target resulted in the buoy and rope being stolen, and the cast-iron skids used have not yet been recovered. Finally, on November 16, the target floated off to sea, dragging a 200-pound anchor, which had been borrowed. Neither the target nor anchor were recovered.

In view of this, I would respectfully recommend that steps be taken to secure three permanent anchorages for future use. These should be at ranges of about 2,700 yards, and 3,700 yards between the two quarantine islands, for practice with the large smooth-bore guns, and siege-gun rifles from Fort Hamilton, and one at a range of about 5,000 yards off Coney Island Point, for practice with the rifle guns from Fort Wadsworth. The anchorage should consist of heavy stones with a long spar-buoy attached by chain in such a manner as to make it difficult for the junk-thieves of the harbor to steal the same. Such spar-buoys could be easily approached by the launch or tug towing the target.

To handle easily an anchor sufficiently heavy to hold the target under all circumstances of wind and tide would involve the necessity of a larger boat than can be obtained and also a larger crew than can be spared.

Besides this, a larger boat could not always approach the anchoring place with or for the target at all stages of the tide, and a target cannot be left out overnight without endangering passing vessels. The spar-buoys will therefore be the more possible solution of the difficulty.

It will be necessary to consult with the Light-House Board as to the location of these spar-buoys, in order that they may not interfere with navigation.

MOVABLE TARGETS.

It is desirable to practice at a movable target as soon as a fair degree of efficiency has been attained at a stationary target. Attached hereto is a sketch of a target given in a paper on artillery practice in Cork Harbor, by Capt. R. A. Montgommery, R. A., published in No. 5, volume 12, of the Proceedings of the Royal Artillery Institute (Fig. 2, *a* and *b* Plate I.)

"The nature of the target used will be easily understood from the two drawings, which are taken from sketches kindly made for this paper by Lieut. F. Bushe, R. A., the adjutant of the Royal Artillery in Cork Harbor.

"Deal planks of scantling, ½ by 10 inches were used, and it was made by the coxswain of the R. A. boat, the material being obtained from the ordnance department.

"The rope was fastened *underneath* the frame-work, so that when the strain came the tendency would be to make the nose of the target rise instead of burying itself, which would be the case if the rope were fastened on the upper surface. The stone shown hanging in rear acted as a counterpoise, helping to lift the nose of the target.

"It was found on trial that even when moving at 8 to 10 knots an hour the target showed no inclination to tow under. The actual rate during practice was 3 to 4 knots an hour. The rope used was a coil of 1½-inch tarred rope, a length of 80 to 100 yards being let out during practice. When testing the target as much as 150 yards was let out without in any way affecting the steadiness of the target."

The sketch appears to give a suitable form for our use when we have more reliable projectiles, but with the older rifle projectiles available, liable as they are to strip, wabble, and tumble, it might not be comfortable for the occupants of a tug towing a target, even if removed 100 or 200 yards.

I would suggest that the target be so arranged as to move freely under action of both wind and tide. Although this might not be as difficult as firing at a vessel moving at full speed, it would answer for our initial efforts and prepare the way for doing good work when better guns and projectiles can be provided.

For practice against a moving target, I would always consider it desirable to fire in volleys of not less than four guns.

GRADUATION OF TRAVERSE CIRCLES.

As preparatory for this work it will be necessary to graduate the traverse circles of the gun to be used. To do this to the requisite degree of smallness of graduations would involve an immense amount of labor. I would therefore suggest two methods of accomplishing the desired result, viz:

1. Graduate the traverse circles to every five degrees; have a pointing-board, similar to the one previously described (see page 114), having five degrees subdivided to any desired smallness of angles. The board is placed so that the extreme graduations of the pointing boards coincide with five degree points on the traverse circles nearest the desired angle. The carriage is then traversed until the pointer on the chassis is at the desired subdivision of the pointing-board.

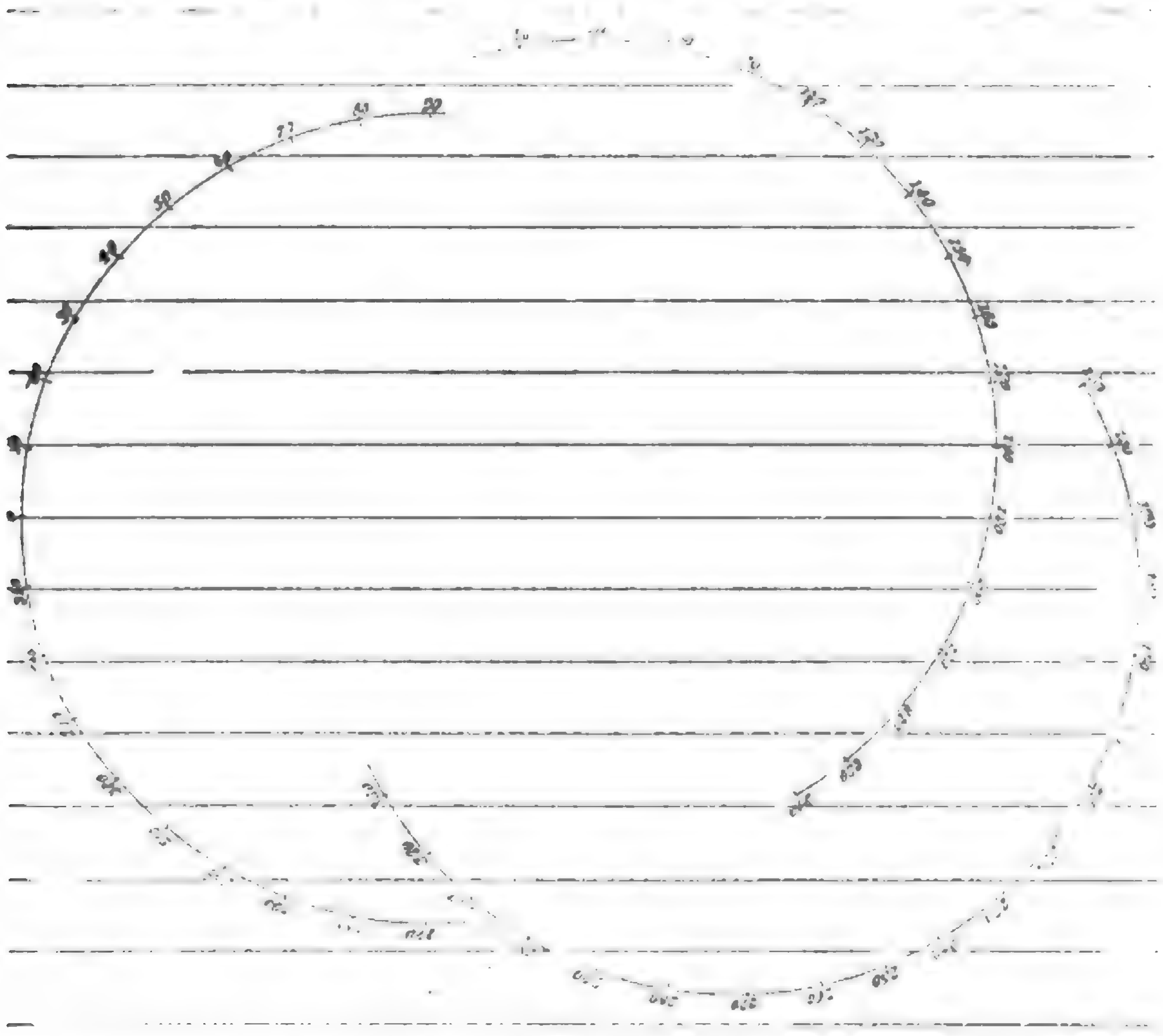
In order to give the pointing-board stability when placed, two powerful bar-magnets might be attached at the extremities of the board. Coming in contact with the iron traverse circle, the magnets would hold the board in position until it is desired to shift it.

2. Graduate the traverse circle to degrees. Attach near to the rear traverse wheel a beveled plate firmly, but so that it may be adjusted, which shall just clear the rear traverse circle. It is to be subdivided to the smallest fraction of degrees required for use.

In view of the imperfect character of the carriages in use—*i. e.*, the play of the gun-carriage on the chassis—it will be necessary to mark on the traverse circles points of reference where the index on chassis should come when gun is sighted upon some well-defined permanent object. The gun being run "in battery," it is sighted upon one of these points, and either the index error noted and used, or else the position of the index be corrected. For each battery a gun shall be indicated as the "directing gun." To the carriages of the other guns to be fired with it in volley a table should be attached giving the difference of angles to be laid off in order to obtain *concentration* of fire at different ranges. Thus when a given angle is noted on the traverse circle of the directing gun the gunners of the other pieces will add or subtract from this angle the amount required for the proposed range of the volley.

To insure parallelism of all angles on traverse circles, it is proposed to make the initial zero line a true north and south line, the zero being at the north and the readings being continuous to 360°, to avoid chances of a gun being traversed to the right when left was intended, and *vice versa*. It will also simplify needed directions to cannoneers.

The ruling of this paper is north and south (meridian line), north being toward left margin. Three examples are indicated:



To successfully execute such firing it will be necessary to point the directing gun some distance in advance of the moving target in the line of its probable motion, and give time for the placement of the other guns in corresponding directions. The gunner of the directing gun allows on his sight for wind and drift and the displacement of the vessel during the probable time of flight plus a small period of time which experience has indicated is requisite for the gunner to remove his sight from the gun and get out of the way. Having so adjusted his sight, when the target is on the medial line of sight he touches a key, which is connected with an electrical firing current, so that the circuit may be closed at the expiration of the period fixed upon.

In the telescopic sights being constructed the gunner is afforded the means of ascertaining within a few seconds the angular displacement of a moving target during the probable time of flight of the projectile, expressed in terms of the deflection scale graduations.

The graduation of the traverse circles will be valuable for use at night and when the field of view is obscured to the gunners by smoke or otherwise.

This involves a perfect system of range-finding in connection with dividing a harbor into suitable-sized squares, &c. Such work cannot be done successfully except with carriages so perfect that when run fully "in battery" the gun shall invariably occupy the same relative position. (See Appendix B.)

TIMES OF FLIGHT.

The times of flight were taken at first with the Auburndale stop watches, giving readings to one-eighth of a second. Having been assured that watches reading to one-tenth of a second could be obtained, no immediate purchase was made, although authority had been granted by the Chief of Ordnance for the purchase of two. Meanwhile the manufacturers (Auburndale Watch Company) had failed, and the eighth-of-second stop watches had to be returned. Efforts are still being made to secure the tenth-of-second stop watches.

It became apparent that times of flight obtained by stop watches alone (except by experts) were not always reliable or uniform, as so much depended upon the personal equation of the observer and the immediate surrounding conditions.

The difficulty lay principally in obtaining the *initial* moment. For this reason, where the firing is by electricity, and particularly if a voltaic firing battery is used, the times can best be attained by a clock-work or register, the *initial* moment being determined by the breaking of the circuit of the electrical primer, and the *final* movement by an observer. The results will be more reliable if this observer is located at some distance from the gun. His momentary personal equation may be registered each time upon seeing the *flash* of the gun, and thus afford a correction for the time of record of the last event. Whilst the small element of time involved may not be of much practical importance for ordinary firing, it is of value in the study of the physical phenomena involved and securing correct conclusions which may be useful for obtaining increased accuracy.

RANGE-FINDING.

The ranges were obtained by means of the plane-tables located near the flag-staffs of Forts Wadsworth and Hamilton, thus giving a base line of 2,151 yards.

The stations were connected with each other, and a station near the guns fired by a telephone line. The plane tables were designed and made at this post, the Ordnance Department having furnished the material and authorized the expenditure for the brass arcs and alidades. A description and sketch of the plane-tables, &c., by Lieut. A. C. Blunt, Fifth Artillery, is given in Appendix A.

The plane-tables being in exposed position, without shelter, it was at times exceedingly uncomfortable for those operating them, and the maximum accuracy could not be expected, particularly when the wind was blowing from 40 to 50 miles per hour, the temperature being, besides, relatively low. Whilst it was extremely desirable to obtain data under these exceptional conditions, it was not to be expected that it should be as accurate as it would otherwise be, or if the observer were properly sheltered. The following incident will illustrate the disadvantage under which some of the observations were made:

The plane-table weighs 103 pounds. Arrangements are attached for clamping it to the stand upon which it is mounted, but owing to its great weight and stability under usual conditions this was ordinarily omitted. On November 6 the wind was blowing about 50 miles per hour, with occasional gusts of even greater velocity. The table was suddenly raised from its pintle by one of these gusts, lifted some distance into the air, and dropped into one of the adjacent trees without injury. The alidade which was lying on it, however, was seriously injured.

In view of this, of the desirability of being able to work under adverse conditions of weather, I would respectfully recommend that a suitable housing be constructed for the plane-table stations. This would be useful not alone for the firing observations, but also for tracking vessels, to which reference will be made hereafter. A suitable covering will make it less difficult to use the telephones, which were hardly audible when a wind was blowing.

MEANS OF COMMUNICATION.

The telephones used were both the Signal Service Crown telephones and the Bell telephones, with Blake transmitters. These last gave the best results. But for this work, when it was desirable to transmit in such manner as to leave no room for doubt, the telephones were not always satisfactory. It is important to transmit in such manner as to leave a permanent record. It is, therefore, proposed to experiment with a pair of Welch & Anders's printing telegraph machines, and a pair of ordinary Morse registers. These printing telegraph instruments are operated by means of a dynamo worked by a treadle. They are similar to a sewing-machine in mounting and appearance, and have a key-board for transmitting. The messages are printed at receiving stations. The telegraphic communication facilities between the two posts are due to the Baltimore and Ohio Railroad Company, which has three seven-core cables laid at the "Narrows," the terminal landings in the Government reservation. In view of this the company has given for our exclusive use one core. Besides this they have put up for us a large proportion of the telegraph lines needed, not alone for the transmission of angles, but also for use in connection with anemometers, &c.

TRACKING-VESSEL DRILL.

The necessity for tracking-vessel drills as a preparation for firing work was made apparent by the delays occurring at times in the range-finding. It is respectfully recommended that frequent exercises be held in tracking vessels and judging distances. (See Appendix B.) These exercises are not alone valuable in themselves, but afford excellent training for rapid, practical work in range-finding during firing.

Appendices C and D give methods of work for tracking vessels and range-finding during artillery practice.

It will be extremely useful in connection with the instruction in this work to give the instruction in the use of the Pratt range-finder, comparing the results obtained with those obtained by the plane-tables.

Notwithstanding the few exercises had in tracking-vessel drills considerable aptitude and skill was displayed by some of those participating. On one occasion at least sixty consecutive observations were made within thirty minutes, an average of one observation for each (30) thirty seconds. This will be better appreciated when it is understood that each complete observation involves the reading and transmission from the auxiliary to the plotting station by telephone of an angle, its plotting on the plane-table of the plotting station, recording angles, and noting time and range.

DEVIATION OBSERVATIONS.

As the splash made by a shot upon striking water is sometimes very large and variable, the locus obtained by the two observers does not always accord in direction, relative to the line of fire, with that seen in rear of the gun. A transit was therefore placed as nearly in rear of the gun as possible. In no single instance did the shot strike so far out of the line as to pass out of the field of the transit except when the projectile tumbled.

A transit is being constructed for our use, the purchase having been authorized by the Chief of Ordanance. It is proposed to place a graduated diaphragm in the eye-piece, so that the observer can read directly the amount of deflection without necessity of moving the instrument or stopping to read external graduations. This diaphragm is removable, and will not interfere with the ordinary uses of the instrument. The graduation will be in spaces of 3 minutes 27 seconds, equivalent to .001 of range. The observer will be able to estimate values of intermediate points.

EXECUTIVE AND RECORD BLANK FORMS.

To facilitate the executive work involved during the artillery practice, and to insure accurate compilation of the physical data obtained by the different observers, as well as to secure finally correct record of all the events involved for future study, the following blank forms were prepared, viz (see Appendix E):

No. 1. Memoranda for the commanding officer of the details of the proposed firing.
No. 2. Instructions to the post quartermaster of services and material required from his department.
No. 3. Instructions to the post ordnance officer of the guns, ammunition, and material required.
No. 4. Details required from a battery.
No. 5. Data to be noted by officer in charge of gun.
No. 6. Deviation observations of transit in rear of gun.
No. 7. Wind velocities and direction corresponding to each round.
No. 8. Plane-table angles during firing.
No. 9. Plane-table angles of the firing pertaining to each battery, and transmitted to battery commanders at the close of the season's firing for plotting.
No. 10. Plane-table angles, range, time, and speed record for tracking-vessel drills.
No. 11. Judging distance and speed.
No. 12. Memoranda furnished by officer supervising firing to officers in charge of guns, giving details of ranges, probable elevation, wind velocity and direction, &c., requisite for pointing.
No. 13. Card of instruction regarding deflection allowances for wind, &c.
No. 14. Form of firing record, both of book and for transmission to Chief of Ordnance.
No. 15. Judging velocity of wind.

The following circular was issued with reference to the company records, &c.:

FORT HAMILTON, NEW YORK HARBOR,
December 21, 1883.

[Artillery Circular No. 1.]

I. Records of artillery firing to be transmitted by battery commanders will conform with the form furnished for that purpose.

The battery-firing record book should also be modified so as to embody the form and data as given. The columns "No. of fire" and "remarks" are to be omitted from the records copied in book. After the records pertaining to a single day's firing, vacant lines should be left for such remarks as may be necessary to complete the history of the day's work, including all incidents which are connected with the extraneous data obtained; behavior of the guns, carriages, and projectiles. In this are to be included remarks as to modifications of means or methods which suggest themselves to battery commanders as a result of the day's experience.

II. The observed angles pertaining to the firing of your battery are hereby transmitted. The firing will be plotted by means of these on the tracking-vessel charts, which are also transmitted herewith.

Care should be taken to distinguish on the plot the firings of different days by difference in character of marks representing the shot. This is particularly important where the firing is at targets nearly in same location. The use of red and black ink is suggested for this purpose, as well as difference of shape of marks, such as circles, squares, and triangles. Each shot should be marked with the number of daily fire, care being taken to make this distinct. The mean position of target should be indicated by a rectangle of about half an inch, with date of firing within.

III. The lines of fire should be given by a dotted red line, and the general direction of the wind indicated by an arrow crossing it. Where the wind changed a number of times a number of arrows should be so marked, indicating on same in red numerals the limits of the round to which they pertain.

GENERAL REMARKS.

It will be seen from the foregoing that much careful work is required in order to obtain the maximum benefit from the firing practice. It demands a perfect coördination of work from a large number of individuals, and the systemization of all details.

It necessarily entails a considerable tax upon the resources of a garrison and may interfere at times somewhat with its ordinary routine, its infantry drills, and small-arms target practice. If, however, we are to be artillery, in fact as well as in uniform and official designation, other work should be subordinated to "artillery practice and instruction." This, to be thoroughly done, to bring ourselves up to the requirements of modern warfare, demands constant work, instruction, and study. Whilst, it is true, we are lacking in modern appliances as to guns, carriages, ammunition, &c., these will be forthcoming, if we exert ourselves sufficiently.

At least single typical guns and carriages with suitable ammunition and appliances may be secured for a post pertaining to each artillery regiment. These posts could be made "regimental schools" of application and instruction and the companies thereat occasionally changed. An increase of the garrisons at these posts will make it more easily practicable to carry out a thorough course of instruction whilst increasing the number participating in the advantages.

It will increase both the corps and regimental *esprit de corps* and efficiency.

It now becomes necessary that all non-commissioned-officers and a large proportion of privates shall receive considerable technical instruction beyond infantry drill and the manuals of the piece. It would therefore appear desirable that they should be selected men and placed on the same footing as to pay and classification as the enlisted men of the Engineer Corps and Ordnance Department.

Besides the work pertaining directly to the manipulation of the guns, non-commissioned officers and some of the more intelligent privates should be instructed in the outlines of electricity, in its application to telegraph and telephone lines and firing batteries, in receiving and transmitting messages by telephone and key and sounders, in transmitting and receiving messages by flags, particularly in receiving messages, in the use of plane-tables and other instruments, &c.

It was the lack of instructed men which hampered us in the work just closed and delayed the obtainment of results as to range, &c., as rapidly as would be demanded for effective service.

Referring to the importance of the special instruction and training which should be given to artillerymen, the following extracts from the royal artillery instruction, gold medal prize essay of 1882, on "The Training of Garrison Artillery for the Attack and Defense of Fortresses," by Col. H. A. Smyth, R. A., are given:

[Extract.]

The armament, of which the practical handling and application belong to the British garrison artillerymen, comprehends the whole of the service, ordnance—from the machine-gun, the Coehorn mortar, and the 7-pounder of 150 pounds weight, up to the 17.72-inch gun of 100 tons, also rockets and hand-grenades. The authorized lists show 48 kinds of rifled pieces and fifty of smooth-bore, including both muzzle and breech systems of loading; their ammunition is of diverse forms, and includes 21 sorts of fuses and 10 sorts of gunpowder; and the carriages from which they are to be fired vary according to the nature and purpose of each piece, under seven separate principles of construction. Besides these fighting carriages, special transporting carriages or apparatus in like variety are necessary for all the heavier pieces employed in fortress warfare; also special machines for shifting, mounting, and moving them, together with instruments and material, in tackles, timber, and iron, for the convenient application of the primary mechanical powers.

Further, the charge and service of magazines, ammunition, and stores; the laboratory duties; the use of range-finders, telescopes, telephones, and field telegraphs; the judgment of distances and of effect of fire; the handling and restoration of platforms, recoil wedges, hydraulic buffers, and anchorages; even the dealing on occasion with horses and their harness, boats and their gear (and in this iron age), the equipment of rail and tram ways, all fall within the office of the complete garrison gunner.

The readiness in combined movements and the state of discipline demanded from the garrison artillerymen (under the second function of training noted above) include competency for long marches, prompt action, and precise formations; also expeditious execution of his co-operative part in any station, in any of the parties serving the weapons and machines, above indicated. If each man can be relied on to perform his particular duty by day and by night, under all adversity of circumstances, whether of heat, cold, wet, privation, difficulty, discouragement, confusion, excitement, or danger from within or without, according to the orders of the officer or non-commissioned officer in immediate charge of the party, then such officer may direct with certainty the action of the unit he commands in just concert with that of others conformably to the instructions he may have received; and thus only may each unit fill its proper place in that scheme of ascending responsibility by adherence to which any army, complete in its manifold parts, becomes capable of working as one whole to carry out the purpose of its general.

The mention of one particular item of armament has been relegated to this place, because the weapon is often held to pertain at least as much to the disciplinary education as to the service equipment of garrison artillery, viz, the carbine, or other rifled small-arm, to be borne by each individual, as is the regular musket in the infantry.

Concerning this weapon it is to be observed that the circumstances are hardly conceivable, in fortress warfare, wherein it could be desirable for the gunner to desist from the service of the guns and employ his carbine against the enemy. In the interests of the interior economy of camps and garrisons it may be well that he should still undertake the ordinary guard of his own quarters, parks, magazines, &c., and for such matters of convenience the establishment of a very small proportion of carbines with the headquarters of each battery would provide; but in the affairs of war, the law that the artilleryman best serves the purpose of the whole to which he belongs by giving himself over completely to his artillery duties, assured of just protection therein by the action of the other arms, must be paramount.

If, then, the artillery carbine comes to be recognized as an instrument for the purposes, not of active service, but rather of domestic training (inasmuch as there results from its exercises and custody and carriage in parades and in maneuvers with other troops, a fairly evident effect on the bearing and apparent discipline of the individual), it must be expected that the kind of spirit developed by its use will prove to be more suitable to the routine of peace-time than to the stresses of war. Traditional custom in the matter of supervision would no doubt undergo some derangement by the general withdrawal of the carbine from the garrison artillery; marching past would be less effective to the eye than heretofore; periodic inspection would see the gunners "on the guns" rather than "under arms," in the reality of shell practice rather than in the dumb-show of musketry exercises; but the display of ability would be more genuine, the effect more practical, and the men, relieved from supererogatory lessons, would devote a fuller and heartier energy towards the mastery of their proper, most weighty, yet sometimes more lightly regarded, duties.

So the garrison artillery, a special arm of fortress warfare, would indeed become less interchangeable with other arms as it progressed in the developments of its own peculiar powers; following therein the universal order of evolution, by which all the branches from a parent stem, the more they advance toward perfection, become the more definitely distinct.

* * * * * * *

Throughout the firing interruptions due to vessels passing near the line of fire seldom exceeded five minutes.

MILITIA ARTILLERY INSTRUCTION.

As in case of foreign war the first troops required would probably be a larger number of artillerists than could be provided by the Regular Army, it becomes incumbent upon us to interest the militia of sea-port towns in this work with a view of some organization, *now* infantry, becoming heavy artillery. For this reason, whenever practicable, the presence of officers of the National Guard was invited, and quite a number were from time to time present at our firing and appeared to be interested in the work.

SUMMARY OF RECOMMENDATIONS.

1. Construction of suitable housings for plane-tables.

2. Frequent tracking vessel drills for the instruction of non-commissioned officers and intelligent privates. Where a sufficient number have become proficient in this for work in day-time, practice in work at night. Practice with the Pratt range-finders in connection with tracking-vessel drills; also, judging distance exercises.

3. Instruction of non-commissioned officers and intelligent privates in sending and receiving messages by flags and torches, by telegraphic keys and sounders, and by telephones. In connection with this a course of elementary lectures on so much of electricity and magnetism as it is necessary to know in the use of telegraph and telephone and manipulation of electrical firing appliances would be desirable.

We have officers fully competent to prepare and give them.

4. Permanent anchorages for targets.

5. Graduation of traverse circles.

Our thanks are due to the following gentlemen:

Messrs. Stewart and Price, superintendents of the Baltimore and Ohio Railroad Company's telegraph lines, for assistance in constructing lines.

Mr. C. A. Hotchkiss, general agent of the Day Kerite Company, for firing cables given for our experiments.

Mr. Humistone, superintendent of the Western Union Telegraph Company, for the loan of two Morse registers.

Mr. Welch, of Boston, for the loan of two Welch & Anders printing telegraphs.

To the Bell Telephone Company for the loan of telephones and transmitters.

DESCRIPTION OF PLANE-TABLES USED AT THE "NARROWS," NEW YORK HARBOR, FOR TRACKING-DRILL AND SHOT-PLOTTING.

[See sketch by Lieut. A. C. Blunt, Fifth Artillery.]

(Fig. 3 of Plate II.)

The tables proper are rectangular, 72 inches long by 48 inches wide, and are constructed of hard wood, 2 inches thick, with every precaution against shrinkage and warping, being carefully braced and grooved.

On each table is a brass arc 122 degrees in amplitude constructed with a radius of 1 meter (39.3708 inches), braced by two brass radial arms, and sunk into the wood so as to be flush with its surface, but not affected by its expansion or contraction. The arc is graduated to degrees and half degrees, numbered at 5 degrees and 10 degrees; these graduating lines are radial, 1 inch in length, bounded by two concentric circles, cut in the brass arc. The zero radius of the arc is parallel to one long side of the table. The alidade is of brass, the rear sight over the center of the arc A, the alidade being pivoted there. The front sight is a little outside the arc, about 40 inches from the rear sights. One edge is in the plane of the line of sight; this is beveled and graduated to millimeters, beginning at the center. Where this edge crosses the arc I, a diagonal vernier V, covering a half degree, is used, reading to minutes on the arc by the intersection of the radial degree and half degree lines with the 30 division of equal parts of the vernier V. The vernier is adjustable by means of the screws attaching it to the alidade.

Around the edges D′ D″ D‴ are three pieces 2 inches thick and 3 inches wide. The grain of the end and side pieces is in the direction indicated by the arrows. The end pieces D′ D‴ are fastened by screws to the width of the board nearest the prolongation of the zero line of graduation. They are fastened by screws to the other marginal piece D″, and are grooved so that the interior boards of the table may expand and contract without affecting the position of the marginal graduation. The piece D″ is screwed to the cross pieces d d d d. These cross pieces are firmly screwed to the board, nearest the zero radial arm of the arc, but at other points of the board the holes for the screws are slotted to permit the boards to expand and contract. An opening of 0.5 inch is left between the boards of the table and D″ to admit of the contraction and expansion of the boards without disturbing the position of D″ relatively to the zero line.

All the boards composing the table were thoroughly seasoned. The tables were covered with several coats of oil and then shellacked.

On these three edges, D′ D″ D‴, a strip of brass 0.5 inch wide is countersunk so as to be flush with the table. On the 0° brass radius, at the exact distance of the other station according to the adopted scale, viz, 1 millimeter = 4 yards, is a thumb-screw B showing the location of the other station when the 0° of the arc is sighted on the station through the alidade. With the screw B as a center, the brass strip is graduated in 5-inch spaces to 122°, the 0° of this graduation being coincident with 180 degrees of the arc graduation. This work was done by placing the 0 degrees of both arcs in the same right line, passing through the centers, the point A of the auxiliary arc being placed over the point B of the other. The graduations of the auxiliary arc are then protracted to the edges of D′ D″ D‴, and smaller divisions cut in by interpolations. By this means the graduation of the strip on each table is the prolonged reproduction of the arc on the other table, the only source of variation between these being the possible slight curvature of the brass used in producing these lines, which error, if any, is constant.

So at either table, after adjusting each 0 degree to sight on the other station, the exact angle taken at the other on any point may be reproduced by using a thread from the screw center B to the given angle on the corresponding graduation; the intersection of this line with the alidade sighted at the same point, at the same time, will give its exact location at that time.

The table is mounted on a cross (X) frame and clamped to it by an eccentric lever, so that after adjustment it will not move. The frame and the table are leveled by four leveling screws, fitting into leveling screws in the cross-arms and into sockets in the stand—an ordinary table stand about 3 feet high with four legs, with braces and a shelf. This stands on a roughly leveled board platform—the location of the station.

No matter what may be the absolute error of graduation in either arc, the method above given of reproducing the graduation on the other table insures the laying off thereon the real angle to the object; and as, on the plotting table, the angle used is due to the actual position of the alidade as sighted on the target or vessel, the locus obtained by these intersections will be correct, both as to position and range, if the point B has been correctly placed with reference to A.

MEMORANDA REGARDING PRACTICAL ARTILLERY INSTRUCTION.

I.—Range and position finding.

A necessary preliminary to effective artillery fire is range and position finding. It is work which should be performed with rapidity as well as precision. The best results can be obtained only by considerable practice with suitable appliances. But few officers and men are required at any one time, and it can be conducted for instruction at times when it may be impracticable to do other artillery work.

Two methods should be practiced: one by regular triangulation, giving accuracy; the other by the use of various range-finders, giving approximation.

The first method requires the establishment of two fixed stations, for plane-tables, as far apart as possible, the distance between them being accurately measured. The stations should be connected with each other by telegraph lines. Where not practicable, owing to intervening water and absence of a cable, the ordinary signal flags and abbreviation code can be used. (See Appendix B.)

Skill in using this method may be obtained by "tracking" vessels after the manner practiced at the torpedo school at Willets Point. The course of a vessel is followed and plotted rapidly upon a chart containing the outlines of the harbor. Thus the absolute position and distance of an object is quickly ascertained.

The charts upon which this is to be done may be drawn at each post from the chart of the harbor furnished by the Engineer Department. Photolithographic copies of these for use may probably be procured from the Ordnance Department. A copy of a chart so procured used at the "Narrows," New York Harbor, is appended, marked E.

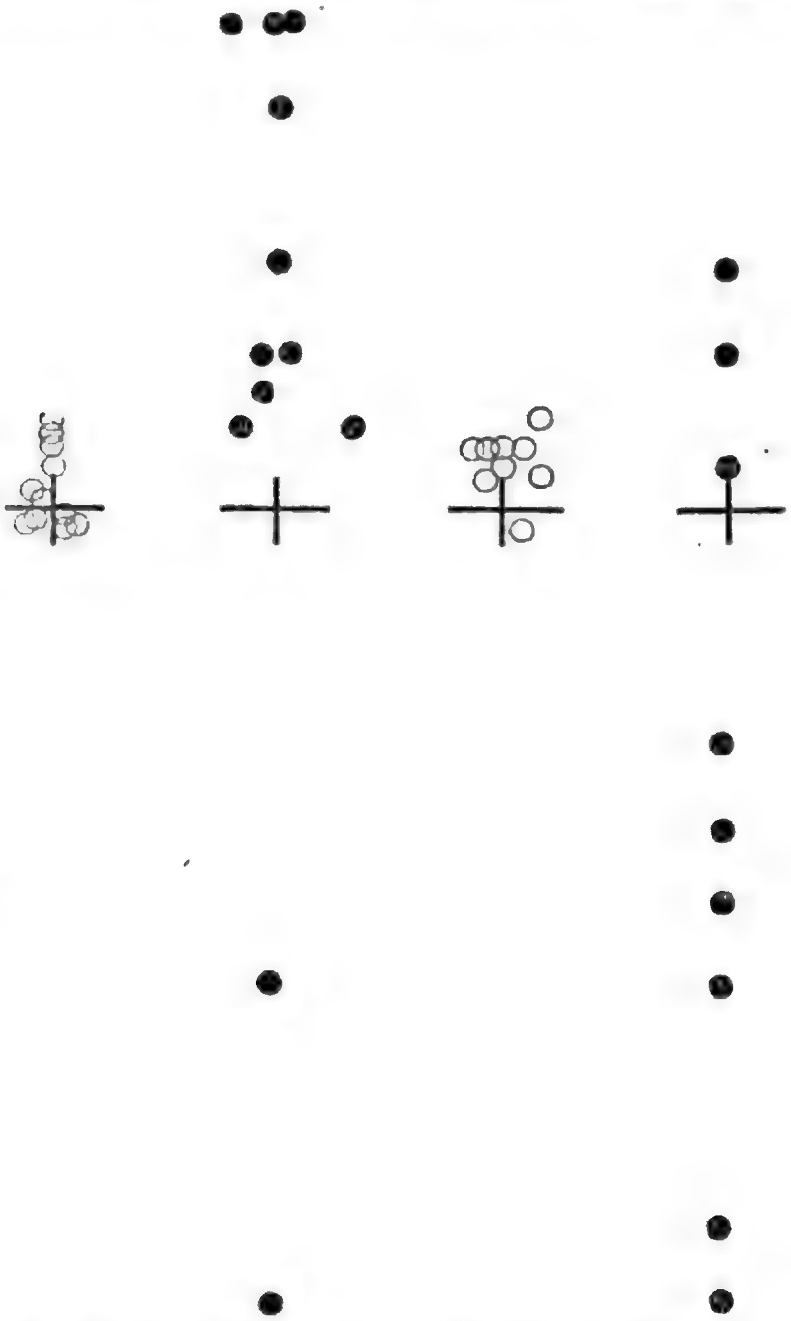
The size should be such as to include the areas covered by the fire of guns of modern construction. The scale of the map referred to is about 200 yards to the inch. The original drawing was by Lieuts. A. C. Blunt and S. E. Allen, Fifth United States Artillery.

The map can also be used for plotting the firing. The auxiliary arcs are used in connection with the border graduation and the diagonal scale of chords given in the legend. Thus neither tables, scales, nor protractors are required; a pair of dividers and two threads sufficing for the work.

The "tracking" drill may be advantageously made also a judging-distance drill. Officers and non-commissioned officers being present at one of the plane-tables, where the course of the vessel is plotted, each one is to be required to note on a tablet or book his estimate of the distance of the vessel at the moment that a record is made. The estimate of the rate of speed in yards per second should also be recorded, as this is an important element in laying a gun upon a moving target. The distance as measured will then be announced and noted in each tablet in a column adjoining the estimate. When the exercise is completed, the errors, plus or minus, are to be noted. A convenient form for this work is given in Appendix C. A table of the speed in yards per second, corresponding to miles per hour, is given in Appendix D. It will be seen that one-half (0.5) yard per second for each mile per hour gives a close approximation easily remembered.

The second method is by the Pratt range-finder, or other similar range-finders. With practice, excellent results can be rapidly obtained by two observers working together.

The gain in accuracy of fire obtained by an efficient system of range and position finding is shown by the following sketch, copied from a paper by Captain Watkins, R. A., published in the Royal United Service Institution Journal. The firing in both instances was at a floating target, the position of all the shot being reduced in the plot to a single position of the target.



Practice under present service condition shown ●

Practice with the aid of the position-finder shown ○

This plate is also given on page 12, Ord. Note 200.

In the case cited the target was towed in a zigzag direction, at rates varying from five to seven knots an hour, and the firing, noted as being aided by the range and position finder, *was carried on with the target invisible to the gunners*, thus assimilating the conditions of a smoke-covered battle-field.

A summary of the material required at each post is given in Appendix A.

II.—ARTILLERY FIRING PRACTICE.

Owing to the constant presence of shipping in our harbor, but little long-range artillery firing appears to have been practiced. The principal object of the existence of artillery is to serve and fire heavy guns effectively. This cannot be done without much practice. It is therefore better to wait hours for opportunities to fire than not to fire at all. It will rarely happen that opportunities to fire will not present themselves in the course of a day, particularly if two targets are placed so as to present somewhat divergent lines of fire.*

The available guns and material are not all that may be desired, but even with these, due care being taken, fair results may be obtained.

It is to be hoped that every important harbor will be provided with at least one gun of each type of modern construction, with suitable carriages for same, to be used in instruction and target practice.

Shell-firing should not be permitted on account of the uncertainty of the available service fuzes, and in the case of smooth-bores the irregular scattering of sometimes large pieces of the wooden sabots.

Smooth-bore mortar firing, giving frequently erratic results, should not be carried on.

While smooth-bore shot and blind shell without sabots may be fired from barbette batteries directly over vessels near at hand, rifled projectiles, manufactured during or immediately after the war, should not be so fired, as they are likely to strip and tumble irregularly. For this reason the latter should not be fired when vessels are in the vicinity of the line of fire.

In all cases the ranges should be such as to preclude the possibility of ricochets. These are frequently irregular and eccentric, particularly those of rifled projectiles.

The present regulation allowance of ammunition is too limited. A large proportion of it is comparatively obsolete and may now be used advantageously only in target practice. The allowance to be expended might, therefore, be increased. It will be found, too, that the regulation allowance at some posts has not been expended in past years, on account of the apparent obstacle presented by the presence of shipping. Authority might be obtained to expend the accumulation of unexpended allowances.

The regulations prescribe firing in the months of June and September, which usually present the most favorable atmospheric conditions. These latter play a very important rôle in affecting accuracy of fire. It is therefore desirable to assign a portion of the firing to periods when the conditions are varied, and even as *unfavorable* as possible. This is particularly marked in winter. As the season when an enemy may attack cannot be assured, the periods when firing practice is had should be so distributed as to include extreme variations of atmospheric conditions. The firing might well be quarterly, assuring one period in winter, at times when the thermometer is below freezing point, and one each in April, July, and November.

In order to increase the chances of making the first fires upon an enemy effective, before the view is obscured by smoke, guns will probably be frequently fired in volleys. It is therefore desirable to practice this firing from five to ten guns simultaneously by electricity. The volley firing should be carried out at the *end* of each period, the elevations, &c., having been obtained by the previous practice. In this practice the graduations of the traverse circle may be advantageously used to secure concentration and rapidity of fire.

The graduation of the traverse circles will also be useful in making deviation allowance for wind and drift where only the old service sights are available. At least two telescopic sights should be obtained for each post, and seats for the same applied to guns of all calibers.

Observations should be taken of the velocity and direction of the wind, particularly during the time of flight. The velocity may be obtained by means of the Signal Service anemometer, arranged to close a bell circuit each tenth of one mile. Readings may thus be obtained within short intervals of time.

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* No harbor in the United States has a commerce equal to that of New York, yet the firing practice from Fort Hamilton during the months of October and November, 1883, was but rarely interrupted by the vicinity of the passing ships, and such interruption never exceeded fifteen minutes.

The following table will be found useful in taking these readings:

Sec.	Miles per hour.									
	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0	....	360	180	120	90	72	60	50	45	40
10	36	33	30	28	26	24	22.5	21.2	20.1	19
20	18	17.1	16.4	15.7	15	14.4	13.8	13.3	12.8	12.4
30	12	11.6	11.2	10.9	10.6	10.3	10	9.8	9.5	9.3
40	9	8.8	8.6	8.4	8.2	8	7.8	7.7	7.5	7.4
50	7.2	7.1	7	6.8	6.6	6.5	6.4	6.3	6.2	6.1
60	6	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.3	5.2
70	5.16	5.10	5	4.93	4.86	4.80	4.73	4.67	4.61	4.55
80	4.50	4.44	4.39	4.34	4.28	4.23	4.20	4.14	4.10	4.05
90	4	3.96	3.91	3.87	3.83	3.79	3.75	3.71	3.67	3.64
100	3.60	3.57	3.53	3.50	3.46	3.43	3.40	3.37	3.33	3.31
110	3.28	3.25	3.23	3.19	3.16	3.13	3.10	3.08	3.05	3.03
120	3	2.98	2.96	2.94	2.91	2.89	2.86	2.84	2.81	2.79

The direction of the wind may be obtained by means of a kite attached to a suitably graduated dial. The graduations of the dial should be in the values of the rectangular components with reference to the line of fire rather than its absolute direction with reference to the points of the compass. (See Appendix C for graduation of dials.) When the wind is insufficient to maintain a kite, the direction may be obtained either with ordinary inflated toy balloons, or else by carefully observing the direction of passage of the smoke.

The times of flight should be carefully noted by at least two observers. The Auburndale stop-watches are excellent and inexpensive. If two are furnished it would be advantageous to have one a "split-timer," in order to take the shortest and longest times of flight in volley firing.

Readings of the barometer, the thermometer, and hygrometer should be taken occasionally during the firing and recorded. The readings should be reduced to the weight per cubic foot of air.

Each shot should be immediately plotted by the means already indicated, and its range noted before another gun of the same caliber is fired. The deviation of the projectile should be noted by an angle-measuring instrument placed as nearly in rear of the piece fired as practicable.

A careful and minute record of the results of the firing and all attendant circumstances should be kept on specially prepared forms. (See Form ——.)

Copies of these should be forwarded to department headquarters for inspection and consolidation at the end of each firing period.

A method should be devised whereby a figure of merit may be assigned to each command and the results published.

When fairly efficient results have been obtained in firing at a fixed target, a movable target should be devised and practiced at.

Interest in the work may possibly be stimulated by an annual competition of gun detachments from each post, the place of competition alternating.

III.—MECHANICAL MANEUVERS.

During the winter, when outdoor work is impracticable, officers and enlisted men should be instructed in various rope-splicing and knots, as also rigging tackle. All should be required to practically make these splices and knots until found efficient therein.

At least once during each year each battery should execute all possible mechanical maneuvers with field and siege guns and mortars, and should have mounted and dismounted a gun and carriage of each caliber under 15 inches, both in barbette and casemate batteries; also raised and lowered these from the parade to the ramparts. At posts where two or more batteries are serving, a 15-inch gun should be dismounted from its carriage and the latter removed fully from its platform, replaced, and the gun remounted. It should also be raised and lowered from the parade to the ramparts, and *vice versa*. The time occupied in these maneuvers should be noted.

Requisitions are to be made upon the Ordnance Department for such appliances as may be needed to execute the foregoing mechanical maneuvers.

An annual report should be made by post commanders specifying the character and dates of the mechanical maneuvers performed by each battery and the entire garrison. The reasons for the non execution of any of the required maneuvers are to be fully given. The details of any accidents occurring during this work are to be stated. In case of serious injury to any officer or enlisted man whilst engaged in mechanical maneuvers, a board of officers should be convened to fully examine into the circumstances of the case and report thereon.

All officers should be invited to offer suggestions in writing regarding modifications of means or methods in range finding, artillery firing, and mechanical maneuvers. The more important ones are to be published in full, others being briefly summarized.

APPENDIX A.

LIST OF MATERIAL REQUIRED AT EACH POST FOR RANGE FINDING AND TARGET PRACTICE.

TO BE FURNISHED BY THE ORDNANCE DEPARTMENT.

Two angle-measuring plane-tables.
One transit.
Two Pratt range-finders.
One 100-foot tape-line.
Two Auburndale stop-watches (split seconds).
One Robinson anemometer.*
One open-circuit bell for same.*
Two Le Clanche cells.*
One aneroid barometer.*
One hygrometer.*
One Laflin & Rand magneto-exploder.
Insulated leading wires.
Two telescopic sights.

NOTE.—The articles marked with * may possibly be supplied by the Signal Department.

TO BE FURNISHED BY THE SIGNAL DEPARTMENT.

Three telegraph keys and sounders.
Three crown telephones and call bells.
Telegraph wire and material, including battery.

It would be advantageous to obtain from the Engineer Department three Wheatstone magneto dial telegraph instruments instead of the telephones. These instruments are in store at Willets Point as a portion of the torpedo outfit, there being a sufficient number for all principal harbors. As the tracking drill forms a necessary portion of torpedo instruction, it may possibly be deemed proper to loan them for the work. They are preferable to telephones, inasmuch as these latter would be inaudible in case of firing. A reliable printing telegraph would be still better.

The probable cost of the necessary appliances for each post would be about $1,000.

The following estimates of the cost per round from the guns, some of which will form our future armament, were taken from the report of the Getty Board, recently published:

6-inch Lyman-Haskell guns	$54 00
6-inch Schultz wire gun	45 00
8-inch wire guns (Ordnance Department)	51 37
8-inch Woodbridge guns	64 50
10-inch Woodbridge guns	90 00
12-inch Woodbridge guns	148 25
12-inch Woodbridge guns	143 14
12-inch M. L. rifled mortar	66 00
10-inch B. L. steel rifle gun	84 90

Only the cost of powder and shot has been included in the foregoing.

Thus it will be seen that only twenty-three rounds of the lightest caliber deemed advisable will more than pay for the outlay at each post required to render the artillery firing effective, and only seven rounds of the largest caliber, a 12-inch rifle.

The cost of the guns mentioned range from $7,148 to $41,170. The mean cost per gun is $26,041, not counting carriage. The cost of a single gun will provide every artillery station in the Army with the means of making their fire effective.

Fort Wadsworth and Fort Hamilton, New York Harbor, are now connected telegraphically by a cable, and the necessary telephones, keys, sounders, &c., have been furnished by the Signal Department, as also two anemometers.

The Ordnance Department has authorized the expenditure for the construction of two angle-measuring plane-tables for these posts, as also for other instruments and materials estimated for.

It will be seen by this that most of the essentials for range finding and artillery firing are now at hand at these posts or are about to be supplied.

APPENDIX B.

METHOD FOR ABBREVIATION OF NUMERALS TO BE USED IN TELEGRAPHING ANGLES BY SIGNALS OR OTHERWISE.

DEVISED BY FIRST LIEUT. G. N. WHISTLER, FIFTH U. S. ARTILLERY.

	a		*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*	*r*	*s*	*t*
A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
C	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
D	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
E	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
F	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
G	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
H	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
I	**21**	**22**	**23**	**2**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**		**34**	**35**	**36**	**37**	**38**	**39**	**40**
J	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**		**54**	**55**	**56**	**57**	**58**	**59**	**60**

Each station is furnished with a card containing above table. Numerals in plain figures refer to degrees; those in bold-faced figures to minutes.

To use the above, telegraph first the letter standing at the top of the column in which the number is found, then the letter at the left of the row in which the number is.

EXAMPLES.

42° 51′ = *b* C — *k* J ; 90° 25′ = *j* E — *e* I, etc.

APPENDIX C.

Judging distance drill at Fort —— on ——.
Name of observer: —— ——.
Character of light, weather, as to sky, clouds, relative position of sun: ——
Weather as to wind, rain, snow, mist, or fog: ——.

Character of vessel and direction of motion.	No. of plane-table record.	Rate of speed, yards per second.	Estimated rate of speed, yards per second.	Estimated distance.	Measured distance.	Error.	Percentage of error.	Remarks.
								Sailing vessel indicate thus ▱ Steamer, thus ⬯ If general direction is towards observer, indicate thus ▱ If away, ▱ If to right or left, thus ▱- or -▱ If stationary, thus φ or ▱-

APPENDIX D.

Judging wind velocity at ——, on ——.
Name of observer, —— ——.

Estimated velocity of wind.	Measured velocity of wind.	Remarks.

APPENDIX E.

Table of speed of vessels in yards per second, corresponding to speed in miles per hour.

Speed in miles per hour.	Speed in miles per second.	Speed in miles per hour.	Speed in miles per second.	Speed in miles per hour.	Speed in miles per second.	Speed in miles per hour.	Speed in miles per second.	Speed in miles per hour.	Speed in miles per second.
1	0.5	6	2.9	11	5.4	16	7.8	21	10.2
2	1.0	7	3.4	12	5.9	17	8.3	22	10.7
3	1.5	8	3.9	13	6.3	18	8.8	23	11.24
4	2.0	9	4.4	14	6.8	19	9.3	24	11.7
5	2.4	10	4.9	15	7.3	20	9.8	25	12.2

One-half yard per second is a close approximation to each mile per hour.

Table of miles per hour, corresponding to knots per hour.

Speed in knots per hour.	Speed in miles per hour.	Speed in knots per hour.	Speed in miles per hour.	Speed in knots per hour.	Speed in miles per hour.	Speed in knots per hour.	Speed in miles per hour.	Speed in knots per hour.	Speed in miles per hour.
1	1.15	6	6.91	11	12.67	16	18.42	21	24.18
2	2.30	7	8.06	12	13.82	17	19.58	22	25.33
3	3.45	8	9.21	13	14.97	18	20.73	23	26.48
4	4.61	8	10.39	14	16.12	19	21.88	24	27.64
5	5.76	10	11.52	15	17.29	20	23.03	25	28.79

A mile is seven-eighths of a knot, approximately.

INSTRUCTION FOR TRACKING VESSELS.

(1.) The two stations will alternate in plotting. One station will be designated "Plotting station," the other "Auxiliary station." The vessel to be tracked and the times of observation will be indicated by the "Plotting station."

(2.) Each plane-table party will consist of five members, designated, respectively, Nos. 1, 2, 3, 4, and 5. The officer in charge of the station will be held responsible for the proper working of all concerned, and he will report any neglect occurring. It is especially enjoined to avoid unnecessary conversation or remarks during the progress of work. Whenever the slightest delay or uncertainty occurs in the use of the telephones the flags should be immediately used, care being taken to transmit *slowly*, with a marked interval between letters. The abbreviation code should be used.

As far as practicable he should cause the numbers to interchange after every two courses jointly tracked. The records should be carefully kept on blanks furnished, all indicated information being embodied.

DETAILED DUTIES OF NUMBERS.

No. 1 adjusts the table so that the zero line will be directed on the opposition station. He keeps the alidade sights upon the vessel, except whilst No. 2 is plotting. In case of small steamers the line of sight is directed upon the smoke-stack. In case of large steamers and sailing vessels it is to be directed upon the foremast of vessels inward bound, and upon the mainmast of vessels outward bound.

No. 1 of the "Plotting station" will call "Ready" just before desirous to make an observation, and "Now" at the instant it is to be made. Sufficient time should elapse between the commands "Ready" and "Now" to assure receipt and acknowledgment at "Auxiliary station." It is well to allow a slight margin for the time involved in transmission. If call-bells are used for this, No. 1 of the "Plotting station" does not bring his alidade to rest until he hears the call-bell ring the signal for "Now." No. 1 of the "Auxiliary station," upon hearing the call-bell ring "Now," or repeated, will at once cease moving his alidade until No. 2 has read the angle. He will then resume the directing of the alidade.

No. 2 reads and announces the angles and protracts the angles received from the "Auxiliary station" upon the corresponding outer graduation. He locates the point on intersections, marking the same with the number of the series of observations, and notes the readings of distances on the alidade.

No. 3 keeps the records and notes the exact time of making observations when at "Plotting station." The alidade readings as given by No. 2 are reduced by No. 3 to yards by multiplying by 4.

No. 4 attends to the telephone, receiving and transmitting messages. The transmission of angles *must* take priority. When telephones are used, the telephones should be on the line and kept to the ears. When not used, No. 4 will place himself at the telescope, reading signals transmitted, &c. The signals "Ready" and "Now," when sent through telephones should be repeated aloud at the "auxiliary station."

No. 5 transmits angles by flags when the telephones are not used, and when not flagging watches the opposite station through the telescope. When at the "plotting station" he indicates "Ready" by raising his flag, and "Now" by dropping it. No. 5 of the "auxiliary station" makes the same movements with his flag, at the same time calling out "Ready" and "Now."

APPENDIX D.

INSTRUCTION FOR RANGE FINDING DURING ARTILLERY PRACTICE.

Each plane-table party to consist of one commissioned officer and three assistants, with the following duties:

No. 1 adjusts the table, directs alidade, and ascertains the distance from the gun.

No. 2 reads the angle of his own table, protracts the angle received from the auxiliary station, and locates the target or shot.

No. 3 manipulates the telephone or key, reads signals when flagged, and keeps record. He will also note the time of flight.

No. 4 flags and renders such assistance as may be required.

At the firing station an additional number is detailed to convey messages to the gun, &c., when telephones are not firing.

The officer in charge of the auxiliary station cannot be too strongly impressed with the necessity of sending the angles of the target and shot immediately. He will suppress all discussions and remarks until this is done. If the telephones fail of immediate action, the angles should be *flagged* at once. When the telephones are in working order the angles will be telephoned. In all cases the angles will be verified by repeating.

The officer in charge of the firing station will cause the angle received from the auxiliary station to be verified, and then plot the position of either shot or target, sending the range immediately to the gun by telephone.

If the latter does not work, he will transmit the range by messenger.

Care should be taken to make the record complete and full. In cases of volleys, the extreme shot to right and left will be noted by pressing the straight edge (accompanying alidade) against the back of the latter, leaving it in position when first shot is noted, passing on to the other extreme shot-splash, taking its angle, and then passing back to the straight edge for the first reading.

When practicable this same method should be pursued in case of ricochets.

As soon as firing is completed for the day, the officers in charge of stations will cause the plane-tables to be properly secured and alidades packed, with all appurtenances of screws, sights, &c., in the alidade-box, and table, alidade, and telephones placed at such as may be directed by the commanding officer. Particular care is to be taken that the connections for telephones, switches, &c., be all properly placed.

A complete record of the day's work is to be made out at once, and given, *duly dated and signed*, to the officer in charge of the firing.

(FORM No. 1, Artillery Practice.)

Memoranda of proposed firing at Fort ——— on ———, 188—.

Guns, detachments, and ammunition.

Calibers.	Battery Nos.	No. detachments.	No. of rounds.	Cartridges.		Projectiles.		Remarks.
				Kind.	Weight.	Shot.	Shell.	

Plane-table details.

Station.	C. O.	N. C. O.	Privates.	Name of officer in charge.	The tables to be in readiness for work at ——— o'clock.
Fort Hamilton					
Fort Wadsworth					

Details to assist officer supervising firing.

Purpose.	C. O.	N. C. O.	Privates.	Time to report.	Remarks.
Ordnance work					
Wind data					
Telephone at gun					
Transit					

(FORM No. 2, Artillery Practice.)

The post quartermaster will cause the target to be anchored at or before ——— of ———, 188—.

He will direct the captain of the launch to report for definite orders to ——— ——— on or before ——— of ———, 188—.

He will also direct ——— ——— to report to ——— ——— for instructions at or before ——— o'clock of ———, 188—.

The following material will be required: ———.

(FORM No. 3, Artillery Practice.)

The post ordnance officer at Fort —— will have in readiness at —— o'clock of ——, 188—, the equipments for the following guns, and ammunition for same:

Calibers.	No. of equipments complete.	Battery No. of gun.	Cartridges.			Projectiles.		Remarks.
			No.	Kind.	Weight.	Shot.	Shell.	

Besides the foregoing the following additional articles will be required, viz:

NOTE.—In each case the brand of powder used should be noted and given to the officer in charge of the firing. The powder of each kind required for the day's firing is to be all thoroughly mixed and weighed under the supervision of a commissioned officer. The weights should be distinctly marked on each cartridge. Shot and shell should be weighed and distinctly marked.

(FORM No. 4, Artillery Practice.)

Details for artillery practice at Fort —— on ——, 188—, from Battery ——, Fifth United States Artillery.

Gun detachment for —— gun; —— ——, officer in charge. Firing to commence at —— o'clock.

For plane-table work at Fort ——, Lieut. —— ——, —— N. C. O., —— privates, to report to —— at —— o'clock.

For transit in rear of gun ——, Lieut. —— —— to report to —— at —— o'clock.

For anemometer readings, &c., —— N. C. O., —— privates, to report to Lieut. —— —— at —— o'clock.

For assistants to Lieut. —— ——at guns —— N. C. O., —— privates, to report to him at —— o'clock.

(FORM No. 5, Artillery Practice.)

Firing data of Battery ——, Fifth United States Artillery, manning guns No. —— at Fort —— on ——, 188—

—— —— ——,
Officer in Charge.

No. daily fire.	Projectile.		Powder.		Sighting.			Apparent amount observed deviation.	Time of flight.	Recoil.	Remarks.
	Kind.	Lbs.	Kind.	Lbs.	Elevation.	Deflection allowance to the—					
						Right.	Left.				

The officer in charge will note any irregular occurrence or incident of the firing of the guns under his charge. He will place himself as nearly in rear of his gun as will permit him to see the shot when it strikes, and he will note whether it strikes in line, to the right or left, and the probable amount of deflection expressed in apparent width of target. He will also note if apparently B. (beyond) or S. (short).

The deflection allowance should be noted in points of sight on pointing board, each point being equivalent to one one-thousandth of the range; range 1,000 equals 1 point.

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

(FORM No. 6, Artillery Practice.)

Record of deviations observed by transit in rear of gun during firing at Fort ——— on ———, 188—.

——— ———,
Observer.

No. of fire.	Directions in minutes.		Remarks. (State how far the transit is placed in rear of gun, and how far to right or left of line of gun and target when not feasible to place on the line; also take angles between F and target.)
	R.	L.	

(FORM No. 7, Artillery Practice.)

Record of wind data during firing at Fort ——— on ——— 188—.

No. of fire.	Direction of wind.				Velocity of wind.		Remarks. (Note the velocity and direction obtained as nearly as practicable whilst the projectile is in the air).
	Deviating components to the—		Accelerating.	Retarding.	Number seconds between the strokes of bell.	Velocity in miles per hour.	
	Right.	Left.					

(FORM No. 8, Artillery Practice.)

Plane-table record at Fort ——— on ——— 188—. Firing from guns No. ———. Fort ———, Lieut. ——— ———, observer in charge.

——— ———,
Assistant.

No. rounds.	No. gun.	Angle at Ft. H.	Angle at Ft. W.	Platted range at Ft. H. or W.	Deflection.		Remarks.
					R.	L.	

(FORM No. 9, Artillery Practice.)

Record of plane-table angles of firing by Battery ——— from Fort ———.

Date, 188—.	No. daily fire.	Caliber guns.	Angle at Fort Hamilton.	Angle at Fort Wadsworth.	Remarks.

(FORM No. 10, Artillery Practice.)

Record of vessel-tracking at the Narrows on ———, 188—. Observers: No. 1, ——— ———; No. 2, ——— ———; No. 3, ——— ———; No. 4, ——— ———.

No. of course tracked.	No. of observation.	Angle at station H.		Angle at station W.		Distance from plotting station.	Distance from previous observation.	Time.	Time from previous observation.	Velocity per second.	Remarks. (Name of plotting station, character of vessel, &c.)
		0.	1.	0.	1.	*Yards.*	*Yards.*	*h. m. s.*	*m. s.*	*Yards.*	

Forms Nos. 11 and 15 will be found in Appendix B.

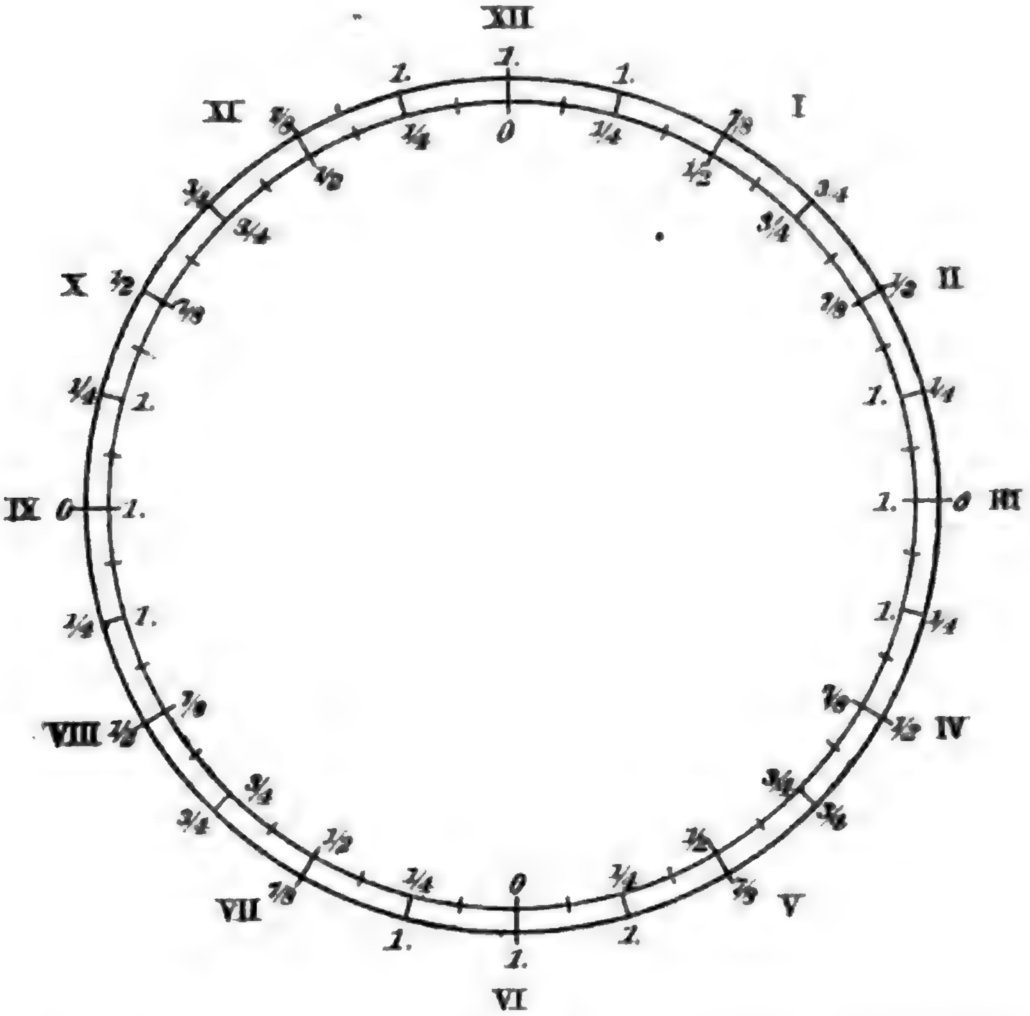
(FORM No. 12, Artillery Practice.)

Range, ——— yards.
Wind velocity, ——— miles.
Direction, ——— o'clock.
Probable elevation, ———.
Coefficient of deviation, ——— yards.
Observed deviation was ———.

[Form No. 13, Artillery Practice.]

Values of rectangular components of wind force.

[Inner sections represent deviating components. Outer represent retarding or accelerating components. Wind = 1.0.]



Multiply wind velocity by fractions of dial to obtain values of components.

Multiply coefficient of deviation for given range by this product, result will be sight allowance required.

Each division of pointing board is equal to $\frac{1}{1000}$ of range. Deviation required divided by value of division of pointing board equals points to take.

FORM No. 14.

Record of artillery firing at Fort Hamilton, N. Y. H.

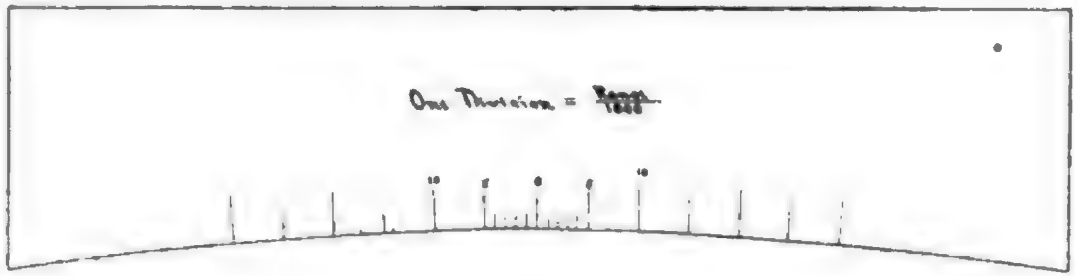
Foundry number of gun.	Date of fire, 1883.	Number of fire.	Powder.		Projectile.		Sight.			Wind, miles per hour.				
			Kind.	Pounds.	Shot.	Shell.	Elevation.	Direction to the—		Velocity.	Rectangular components to the—			
								Right.	Left.		Right.	Left.		
					lbs.	*lbs.*								

Atmosphere.				Time of flight.	Range in yards.	Observed deviation to the—		Pressure.	Recoil.	Officer in charge of gun.
Barometer.	Thermometer.	Hygrometer.	Weight per cubic foot of air.			Right.	Left.			

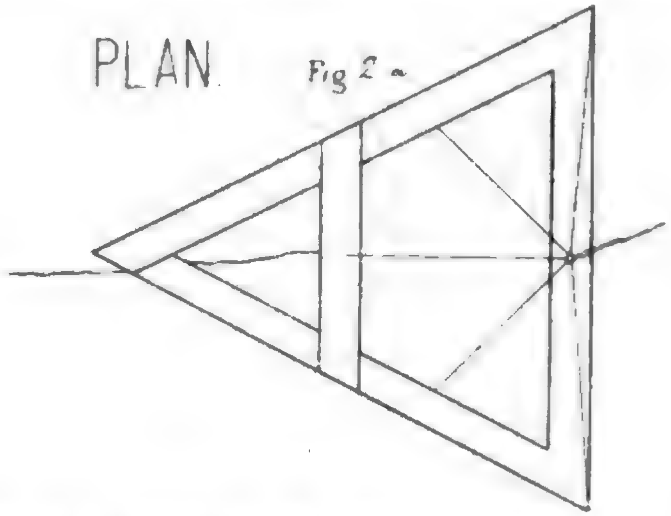
PLATE I

POINTING BOARD

Fig 1.

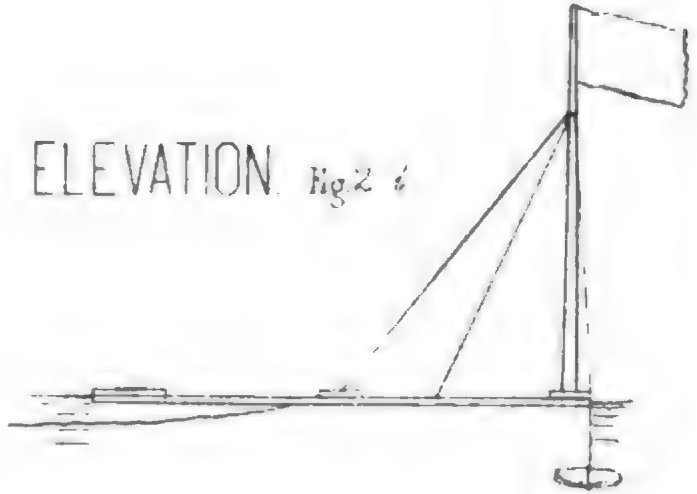


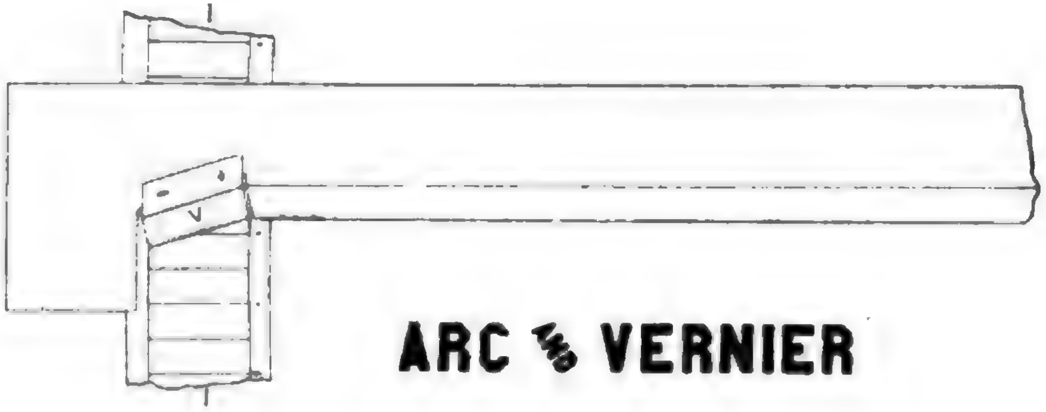
PLAN. Fig 2 a



FLOATING TARGET

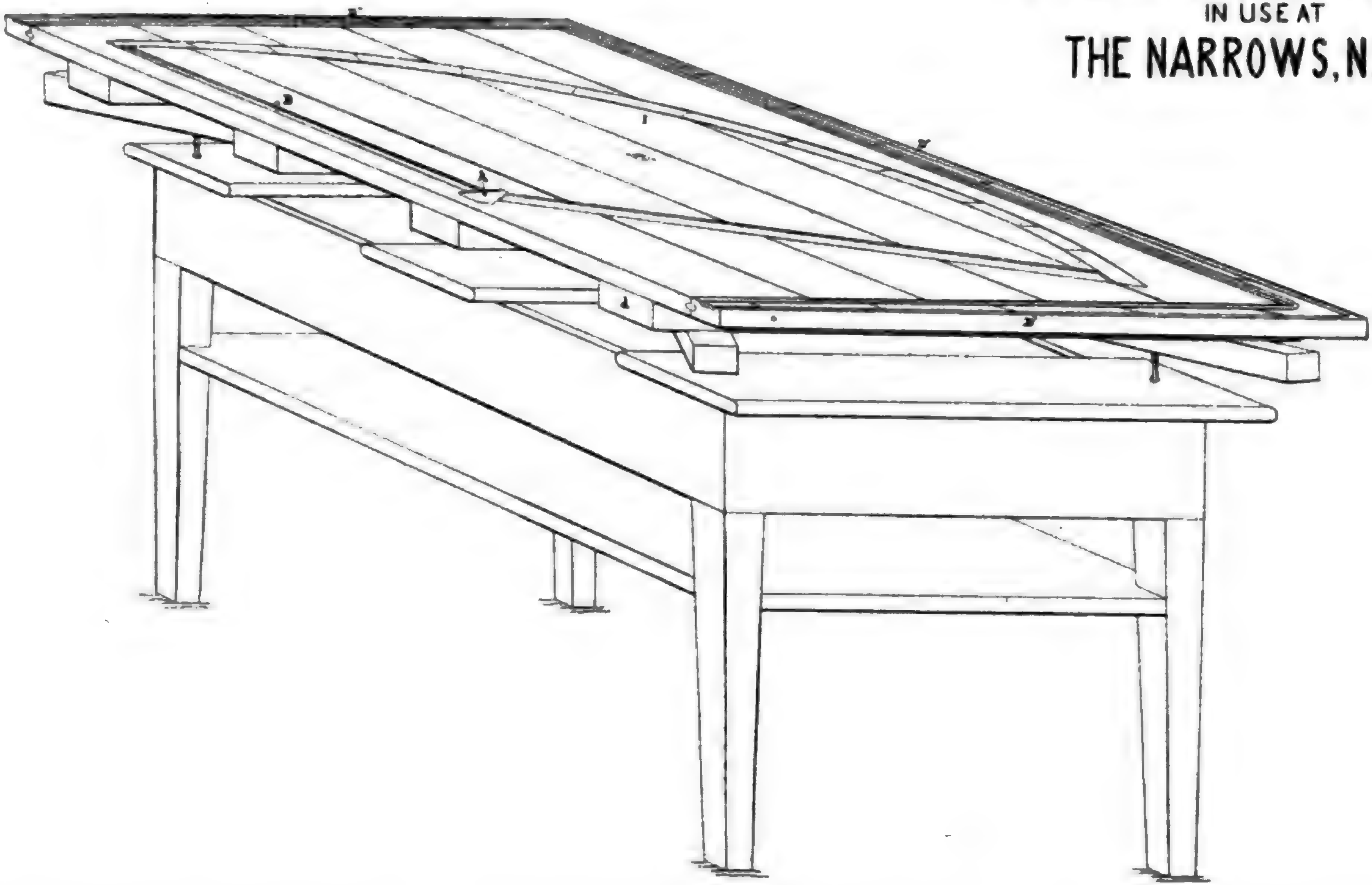
ELEVATION. Fig 2 b

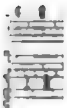




ARC AND VERNIER

PLANE TABLE
IN USE AT
THE NARROWS, N.Y.H.





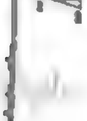


PLATE III

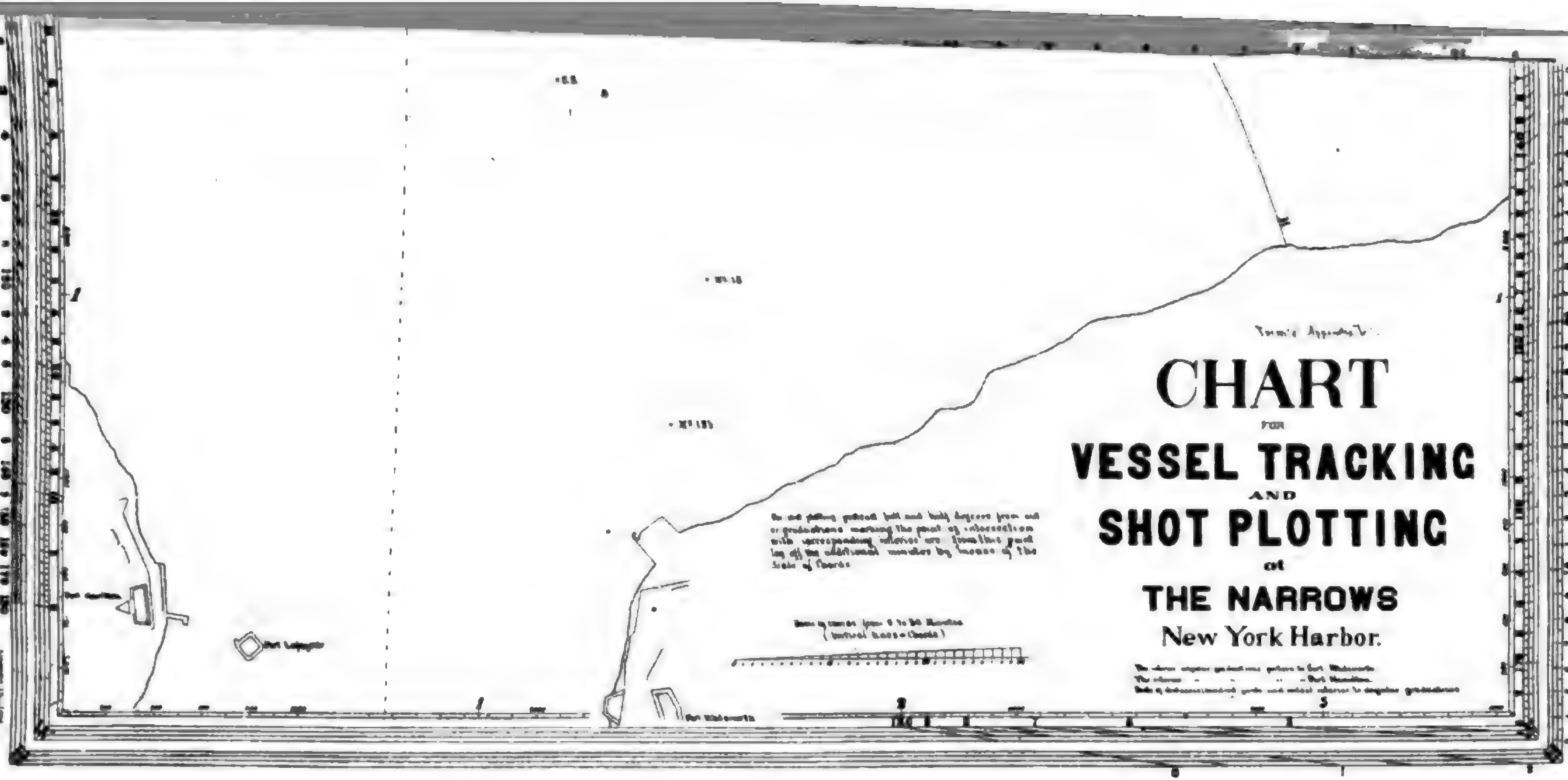


CHART
FOR
VESSEL TRACKING
AND
SHOT PLOTTING
at
THE NARROWS
New York Harbor.

APPENDIX 14.

PARTIAL TRIAL OF A 3.2 INCH STEEL FIELD GUN AND STEEL GUN CARRIAGE BY THE ORDNANCE BOARD.

(4 plates.)

The gun, constructed of steel furnished by the Midvale Steel Company, was fabricated at Watertown Arsenal. Its design was substantially that shown in the plate to Appendix 31 to the report of the Chief of Ordnance for 1883. Certain changes in detail were made as the work progressed, and are, it is supposed, described in the construction report of the gun. The breech mechanism was so arranged that either the De Bange or the Freyre gas-check could be used.

The De Bange check (Plate 1 Fig. 1) is composed of a breech-screw with an interrupted thread, traversed in the direction of its axis by a spindle terminating in a head shaped like a mushroom. The head receives the pressure of the powder gases and is supported by a plastic material interposed between it and the face of the breech-screw; the plastic material effects the obturation. The plastic substance employed is composed of asbestos and tallow contained in an envelope of cloth and sustained by two cup-shaped copper rings.

The Freyre check (Plate 1 Fig. 2) consists of a breech screw with an interrupted thread, traversed axially by a spindle. The spindle terminates in a head having the form of a conical frustum. The head is embraced by a ring with a conical interior surface and an exterior surface in light contact with the walls of the gun. The base of the ring rests against the face of the breech screw, and the interior surface of the ring is so adjusted as to cause a slight space to exist between the head and the face of the breech-screw. When the powder gases act, the head is forced back through the space above referred to and the ring is expanded into firm contact with its seat, thus preventing escape of gas.

The powder chamber was so constructed that a charge of 3.5 pounds of powder could be used when the De Bange check was in place. It followed that when the Freyre check was substituted the powder space was unnecessarily large, but the pressure which would result was considered sufficient to try thoroughly this mechanism. While there was but little doubt that the De Bange system would work well it is considered objectionable for use in a field gun where lightness is of great importance. As the drawings show, the use of the De Bange check requires an increase in the length of the gun at that part which gives the greatest increase to the weight.

The carriage of steel was made at Watervliet Arsenal, and was similar in design to that illustrated in Appendix No. 32 of the Report of the Chief of Ordnance for 1883.

The powder for the trial was Du Pont's I K, granulation 2200, density 1.725. It had previously been recommended for use in the field service.

The projectile used was a cast-iron shell with a solid copper band made as described in Ordnance Board Report No. 22, 1884, sent to the

Ordnance Office June 19, 1884. The weight of the projectile filled is 13 pounds.

The trial commenced July 10, 1884, with the Freyre gas check. Two rounds were fired with 3 pounds, three rounds with 3.25 pounds of powder in order to try the check and fit it to its place. Thereafter the charges fired weighed 3.5 pounds until the end of the sixtieth round, when, by direction of the Chief of Ordnance, the gun was transferred from the Ordnance Board to the "Board for Testing Rifled Cannon," &c.

The Freyre check completely prevented the escape of gas, but gave trouble by sticking after the first few rounds. This difficulty was obviated later as will be shown by the report of the board for testing rifled cannon, &c.

Tables showing total enlargements and firing records for the first sixty rounds are inclosed. From the latter the following summary is obtained:

Initial velocity (mean of 18 rounds)	feet	1,635
Pressure (mean of 25 rounds)	pounds per square inch	29,116
Energy:		
Total	foot-tons	241.29
Square inch of cross section	do	29.99
Per pound of powder	do	68.91
Per pound weight of piece	foot-pounds	681.33
Per cent. realized		78

For comparison a table is appended giving data for foreign pieces of similar character, extracted from the Report of the Chief of Ordnance for 1883.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Nation or manufacture.	Denomination.	Material.	Caliber, inches.	Weight, pounds.	Length.			Twist.	
					Total, inches.	Bore.			
						Inches.	Caliber.	Feet.	Caliber.
American	....	Steel jacketed	3.2	793	90.8	83.2	26.	....	30
German	8-pdr., mod. '73	Steel hooped	3.09	858	82.67	74.21	24.		50
French	8^{cm}	Steel hooped	3.15	935	89.76	83.54	26.5	1° 7′	to 30°
Russian	....	Steel hooped, Krupp, mod. '77.	3.45	793	66.93	57.68	16.8	....	8 to 36
Russian	....	Steel hooped, Russian, mod. '79.	3.43	802	66.93	57.68	16.8	....	8 to 36
American	M. L.	Wrought iron	3.	820	......	64.5	21.5	....	....
English	13-pdr	Steel, wrought-iron jacket	3.	952	89.	84.	28.	....	30
Armstrong (Spanish).	8^{cm} (7.6^{cm})	Steel, wrought-iron jacket, M. L. & B. L.	3.	925	85.	81.49	27.	*	......
Spanish	8^{cm}	Steel jacketed, Sotomayer	3.15	532.4	87.08	80.71	25.6	†	......
French	8^{cm}	Steel hooped	3.15	935	89.76	83.54	26.5	1° 7′	to 30°
Swiss	8.4^{cm}	Steel hooped, Krupp	3.307	935	84.65	76.06	23.	‡	......
Italian	9^{cm} (8.7^{cm})	Steel hooped, Krupp	3.425	1,082	83.46	74.	21.5	..	46
Russian	....	Steel hooped, Krupp, mod. '77.	3.43	973	82.68	73.43	21.4	....	8 to 40
Russian	....	Steel hooped, Russian, '79	3.43	1,005	82.68	73.43	21.4	...	8 to 40
Austrian	....	Compressed bronze wedge fermeture.	3.43	1,071	81.10	72.05	21.	..	46
German	9^{cm}, mod. '73	Steel hooped	3.46	990	82.67	73.43	21.	....	50

* Increasing to 3 calibers, then uniform.
† Increasing 1 turn in 50 to 1 in 22.
‡ Increasing final 1 in 42.

Grooved.			Powder chamber.		Powder charge.		Projectile.				Muzzle energy.			
Width, inches.	Depth, inches.	Number.	Length, inches.	Diameter, inches.	Weight, pounds.	Nature.	Length, caliber.	Weight, pounds.	Initial velocity, feet.	Pressure per square inch, pounds.	Total foot-tons.	Sq. inch shots, cross section, foot-tons.	Per pound of powder, foot-tons.	Per pound of weight of gun, ft.-pounds.
......	......	...	*10. †11. 4	...	3. 5	Gr.2200, D. 1.725	‡2. 8	13.	1, 635	29, 116	241. 2	29. 99	68 9	681. 33
......	0. 049	24	13. 97	.....	2. 75	....	2. 5	11. 15	1, 522	......	179. 0	24.	65.	467.
0. 31	......	24	16. 33	3. 27	3. 3	Gr. 24, D. 1.745.	2. 8	12. 3	1, 607	......	220. 2	28.	67.	520.
0. 33	0. 049	24	11. 43	3. 86	2. 99	....	‡2. 36	15. 12	1, 350	......	191. 0	20. 4	63.	540.
0. 33	0. 049	24	11. 43	3. 86	2. 99	....	2. 36	15. 12	1, 350	......	191. 0	20. 6	63.	533.
0. 5	0. 05	13	11. 5	3. 5	3. 125	R. L. G........	‡3. 16	13.	1, 595		230. 8	32. 4	73. 6	543.
0. 498	0. 047	...	12. 27	3. 7	3. 5	....	.....	13.	1, 600	28, 000	230. 7	32. 4	65. 6	558.
......	0. 0197	16	13. 32	3. 54	3. 41	Cubic (density 1.76) 11^{mm}.	3.	13. 86	1, 492	......	214.	27. 4	62. 7	900.
0. 31	......	24	16. 33	3. 27	3. 3	Gr. 24, D. 1.745.	2. 8	12. 3	1, 607	......	220. 2	28. 2	66. 7	527.
0. 314	0. 049	24	......	.....	3. 08	D. 1.64, G.29x39	......	13. 71	1, 502	.....	214. 4	24.	69. 6	513.
0. 30	0. 043	24	......	.....	3. 19	D. 1.67, Gr. .276 to .430.	......	15. 14	1, 490	30, 000	233. 0	25. 3	73.	482.
0. 33	0. 049	24	10. 75	3. 86	2. 99	....	‡2. 36	15. 12	1, 450	......	220. 3	23. 9	73. 6	507.
0. 33	0. 049	24	10. 73	3. 86	2. 99	....	2. 36	15. 12	1, 450	......	220. 3	23. 9	73. 6	491.
0. 318	0. 049	24	13. 78	...	3. 3	Aust. field	2. 5	13. 97	1, 476	......	210. 9	22. 8	63. 9	442.
......	0. 049	24	14. 57	...	3. 6	....	2. 5	15. 4	1, 460	......	227. 6	24.	63. 2	515.

* DeBange. † Freyre. ‡ Shell.

Table showing enlargement of bore and powder chamber of 3.2-inch breech-loading rifles (steel).

Inches from muzzle.	Original diameter of bore.	Diameter of bore after 60 rounds.	Enlargement.	Inches from muzzle.	Original diameter of bore.	Diameter of bore after 60 rounds.	Enlargement.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
70	3.207	3.215	0.008	35	3.205	3.207	.002
69	3.207	3.214	.007	34	3.205	3.207	.002
68	3.207	3.214	.007	33	3.205	3.207	.002
67	3.207	3.214	.007	32	3.205	3.207	.002
66	3.207	3.214	.007	31	3.204	3.207	.003
65	3.207	3.213	.006	30	3.204	3.207	.003
64	3.206	3.212	.006	29	3.204	3.207	.003
63	3.206	3.211	.005	28	3.204	3.207	.003
62	3.206	3.211	.005	27	3.204	3.207	.003
61	3.206	3.210	.005	26	3.204	3.207	.003
60	3.206	3.210	.004	25	3.204	3.207	.003
59	3.205	3.210	.005	24	3.203	3.207	.004
58	3.205	3.209	.004	23	3.203	3.206	.003
57	3.205	3.209	.004	22	3.203	3.206	.003
56	3.205	3.209	.004	21	3.204	3.206	.002
55	3.205	3.209	.004	20	3.204	3.206	.002
54	3.205	3.209	.004	19	3.204	3.206	.002
53	3.205	3.209	.004	18	3.204	3.206	.002
52	3.205	3.209	.004	17	3.204	3.206	.002
51	3.205	3.209	.004	16	3.205	3.206	.001
50	3.205	3.209	.001	15	3.205	3.206	.001
49	3.205	3.208	.003	14	3.205	3.206	.001
48	3.205	3.208	.003	13	3.205	3.206	.001
47	3.205	3.208	.003	12	3.205	3.206	.001
46	3.205	3.207	.002	11	3.205	3.206	.001
45	3.205	3.207	.002	10	3.205	3.206	.001
44	3.205	3.208	.003	9	3.205	3.206	.001
43	3.205	3.207	.002	8	3.205	3.207	.002
42	3.205	3.207	.002	7	3.205	3.207	.002
41	3.205	3.207	.002	6	3.207	3.208	.001
40	3.205	3.208	.003	5	3.207	3.208	.001
39	3.205	3.208	.003	4	3.208	3.208	.000
38	3.205	3.208	.003	3	3.208	3.208	.000
37	3.205	3.208	.003	2	3.207	3.208	.001
36	3.205	3.207	.002	1	3.207	3.208	.001

POWDER CHAMBER.

Inches from breech.	Diameter before firing.	Diameter after 60 rounds.	Enlargement.
	Inches.	*Inches.*	*Inches.*
11.2	3.768	3.768	0.000
13.2	3.81	3.813	.003
15.2	3.755	3.713	— .042

Record of firing with 3.2-inch breech-loading rifle (steel), at

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength, and direction.
			Kind.	Weight.		Kind.	Weight.						
		1884.		Lbs.	Oz.		Lbs.	Oz.	° '	Lbs.	Feet.	Feet.	
Barometer, 29.850; thermometer, 73.7; humidity, 63.	1	July 10	Dupont's I K. D; density, 1.725; granulation 2200.	3	...	Solid band experimental shell (new); band 3".30 diameter, 0".5 wide, beveled front and rear.	13	...	0	23,700	1,519	6.50	From front and right 48°, 12 miles an hour.
	2	July 10		3	...		13	....	0	24,700	1,482	5.42	
	3	July 10		3	4		13	...	0	26,500	1,558	7.58	
	4	July 10		3	4		13	..	0	26,350	1,557	6.50	
	5	July 10		3	4		13	....	0	25,200	1,554	7.00	
Barometer, 29.899; thermometer, 77.2; humidity, 69.	6	July 11		3	8	Solid band experimental shell (old); band 3".30 diameter, 0".5 wide; beveled front and rear.	13	....	0	29,500	1,623	8.00	From front, 18 miles an hour.
											129½'		
	7	July 11		3	8		13	....	2 30	30,200	1,602	8.00	
	8	July 11		3	8		13	....	2 30	30,900	1,603	8.00	
	9	July 11		3	8		13	....	2 30	28,900	1,612	8.16	
Barometer, 29.818; thermometer, 66.7; humidity, 57.	10	July 16		3	8		13	....	−¼	30,900	1,629	9.00	From front and left 3°; 7 miles an hour.
	11	July 16		3	8		13	...	2 32	30,700	....	7.50	
	12	July 16		3	8		13	....	2 30	30,500	......	7.75	
	13	July 16		3	8		13	....	2 30	29,900	.....	8.00	
	14	July 16		3	8		13	....	2 30	29,800	....	8.00	
	15	July 16		3	8		13	...	2 30	28,800	....	8.00	
	16	July 16		3	8		13	....	2 30	28,900	......	8.50	

Sandy Hook, N. J., from July 10 to July 24, 1884.

Distance from center of target, in feet.				Distance from center of impact, in feet.					Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Vertical.		Horizontal.		Vertical.		Horizontal.			
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.		
Fired into sand butt...									Gas escaped uniformly all around gas check. Before next round obturator set out 7-thousandths of an inch. Faint trace of gas escape on top. Lid of trail chest being unlocked, hasp in chest jarred off and thrown out. Slight traces of gas escape. Slight traces of gas escape. Gun washed out, examined, star-gauged, and impressions taken, no gas escape. Before firing round No. 6 the outer surfaces of gas ring, of carrier ring, and of horizontal surfaces of obturator stem were slightly ground down and the obturator plate was pinned to the breech block to prevent turning.
....									No gas escape in round No. 6; opened with some difficulty.
....	7.75	....	0.75	....	2.42	....	2.00	Fired at mile target.	Good flight. Slight escape of gas all around check. Opened with considerable difficulty.
....	2.24	2.50	....	3.00	....	1.25	....		Good flight. Slight escape of gas all around check. Opened with but slight difficulty.
....	6.00	2.00	....	....	.67	.75	....		Good flight. Slight escape of gas all around check. Opened with but slight difficulty.
....	15.90	4.50	0.75	3.00	3.09	2.00	2.00		
15.90÷3=5.33		3.75÷3	1.25	6.18÷3=2.06		4.00÷3=1.33			
Mean vertical deviation from center of impact........2′.06 Mean horizontal deviation from center of impact.....1′.33 Mean deviation from center of impact..................2′.45									Gun washed out, examined, star-gauged, and impressions taken.
Fired into sand butt..........									
Fired at mile target. Sighting shot..........									Good flight.
....	5.25	....	1.00	....	3.75	....	3.88	Fired at mile target.	Do.
....	2.50	3.00	....	....	1.00	.12	....		Do.
....	....	11.00	....	1.50	....	8.12	....		Do.
Missed target		....	....	....	....	....	....		Good flight. It is possible that this shot passed through an old hole in the target.
1.75	....	....	1.48	3.25	....	....	4.36		Good flight.
1.75	7.75	14.00	2.48	4.75	4.75	8.24	8.24		
6.00÷4=1.50		11.52÷4=2.88		9.50÷4=2.37		16.48÷4=4.12			
Mean vertical deviation from center of impact.........2′.37 Mean horizontal deviation from center of impact.....4′.12 Mean deviation from center of impact..................4′.75									Gun washed out, examined, star-gauged, and impressions taken. Rounds 10, 11, 12, 13, 14, 15, and 16 gun opened with difficulty by hand. No gas escape.

Record of firing with 3.2-inch breech-loading rifle (steel), at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength, and direction.
			Kind.	Weight.		Kind.	Weight.						
		1884.		Lbs.	Oz.		Lbs.	Oz.	° ′	Lbs.	Feet.	Feet.	
Barometer, 29.930; thermometer, 82.4; humidity, 48.	17	July 22	Du Pont's I. K. D.; density, 1.725; granulation, 2200.	3	8	Solid-band experimental shell; band 3".30 diameter, 0".5 wide; beveled front and rear.	*13	....	0	29,800	1,632	9.00	From rear and right, 87°; 20 miles an hour.
	18	July 22		3	8		†13	....	0	27,900	1,605	9.00	
	19	July 22		3	8		†13	....	0	28,600	1,608	9.00	
	20	July 22		3	8		†13	8	0	28,650	1,577	10.00	
	21	July 22		3	8		†13	8	0	29,300	1,572	10.00	
	22	July 22		3	8		†13	8	0	29,100	1,580	10.00	
	23	July 22		3	8		†15	....	0	30,700	1,514	11.00	
Barometer, 29.921; thermometer, 84.7; humidity, 48.	24	July 23		3	8	Solid-band experimental shell (new); band 3".30 diameter, 0".5 wide; beveled front and rear. Condemned lot, except round 33.	13	....	2 30	....	....	7.83	From front and right, 3°; 7 miles an hour.
	25	July 23		3	8		13	....	2 30	....	....	8.50	
	26	July 23		3	8		13	....	2 30	....	....	8.25	
	27	July 23		3	8		13	....	2 30	....	....	8.50	From front and right, 48°; 8 miles an hour.
	28	July 23		3	8		13	....	2 30	....	....	8.16	
	29	July 23		3	8		13	....	2 30	....	....	8.16	
	30	July 23		3	8		13	....	2 30	....	....	8.50	
	31	July 23		3	8		13	....	2 30	....	....	8.50	
	32	July 23		3	8		13	....	2 30	....	....	8.83	
	33	July 23		3	8		13	....	2 30	....	....	8.50	
Barometer, 29.822; thermometer, 89.8; humidity, 34.	34	July 23		3	8		13	....	0	28,800	1,608	9.00	Front and right, 48°; 18 miles an hour.
	35	July 23		3	8		13	....	0	28,400	1,619	9.16	
	36	July 23		3	8		13	....	0	29,100	1,624	9.50	
	37	July 23		3	8		13	....	0	29,600	1,632	9.00	
	38	July 23		3	8		13	....	0	27,700	1,630	9.00	
	39	July 23		3	8		13	....	0	29,600	1,618	9.00	
	40	July 23		3	8		13	....	0	29,500	1,610	9.75	
	41	July 23		3	8		13	....	0	29,100	1,609	9.50	
	42	July 23		3	8		13	...	0	28,200	1,608	10.00	
	43	July 23		3	8		13	....	0	28,800	1,597	10.33	

*Old. †New.

Hook, N. J., from July 10 *to July* 24, 1884—Continued.

Distance from center of target, in feet.				Distance from center of impact, in feet.					Special remarks about each fire such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Vertical.		Horizontal.		Vertical.		Horizontal.			
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.		
Fired into sand butt.									
									Gun washed out, examined, star-gauged, and impressions taken.
....	3.26	....	2.50	....	4.59	5.50	....	Fired at mile target; target 20' x 40', made of 1" spruce boards.	Good flight.
....	4.00	....	2.50	....	5.33	5.50	....		Do.
7.23	....	....	5.50	5.90	....	2.50	....		Do.
1.50	....	....	7.50	0.17	....	0.50	....		Do.
....	1.00	....	5.00	....	2.33	3.00	....		Do.
Over target.		....	....	....	....	....	....		Do.
6.00	....	....	14.00	4.67	....	....	6.00		Do.
4.50	....	....	9.50	3.17	....	....	1.50		Do.
....	3.50	....	11.00	....	4.83	....	3.00		Do.
4.50	....	....	14.50	3.17	....	....	6.50		Do.
23.73	11.76	....	72.00	17.08	17.08	17.00	17.00		
11.97÷9=1.33		72÷9=8.00		34.16÷9=3.80		34.00÷9=3.78			

Mean vertical deviation from center of impact .... 3'.80
Mean horizontal deviation from center of impact ...... 3'.78
Mean deviation from center of impact .... 5'.36

Gun washed out, examined, star-gauged, and impressions taken.

Fired into sand butt.

Record of firing with 3.2-inch breech-loading rifle (steel), at Sandy

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore (crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.
			Kind.	Weight.		Kind.	Weight.					
		1884.		*Lbs.*	*Oz.*		*Lbs.*	*Oz.*	° ′	*Lbs.*	*Feet.*	*Feet.*
Barometer, 29.822; thermometer, 89.8; humidity, 34.—Continued.	44	July 23	Du Pont's I. K. D. Density, 1.725. Granulation, 2200.	3	8	Solid band, experimental shell (new), band 3″.30 diameter, 0″.5 wide, condemned lot, beveled front and rear.	13	....	0	29,300	1,599	10.00
	45	July 23		3	8		13	....	0	29,500	1,601	11.00
	46	July 23		3	8		13	....	0	28,900	1,605	10.00
	47	July 23		3	8		13	....	0	28,800	1,604	10.50
	48	July 23		3	8		13	....	0	28,700	1,601	9.75
	49	July 23		3	8	Solid band, experimental shell (new), band 3″.30 diameter, 0″.5 wide, beveled front and rear.	13	....	0	29,300	1,604	10.50
	50	July 23		3	8		13	....	0	28,800	1,604	10.33
Barometer, 29.904; thermometer, 80.3; humidity, 63.	51	July 24		3	8	Solid band, experimental shell (resobated), band 3″.30 diameter, 0″.5 wide, beveled front and rear.	13	....	15	....	....	6.50
	52	July 24		3	8		13	....	15	....	....	5.00
	53	July 24		3	8		13	....	15	....	....	6.25
	54	July 24		3	8		13	....	15	....	....	6.75
	55	July 24		3	8		13	....	15	....	....	6.00
	56	July 24		3	8		13	....	23	....	....	6.00
	57	July 24		3	8		13	..	23	....	......	5.25
	58	July 24		3	8		13	....	23	....	....	5.50
	59	July 24		3	8		13	...	23	....	....	6.00
	60	July 24		3	8		13	....	23	....	......	5.50

Hook, N. J., from July 10 *to July* 24, 1884—Continued.

Wind, strength, and direction.	Time of flight.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
	″			
From front and right, 48°. 18 miles an hour.	......	Fired into sand butt.		
	......			
	......			
	......			
	......			
	......			
	......			Gun washed out, examined, star-gauged and impressions taken.
From rear and right 54°. 8 miles an hour.	Lost.	Fired to sea.	Fired to test carriage. The hinge bolts of trail-chest lid were both broken, and a slight bucking of left cheek and lifting of flange at junction of reinforcing plate was (almost imperceptibly) increased.	Good flight.
	Lost.			
	19½			
	19¾			
	19½			
	28			
	28			
	28			
	28			Gun washed out, examined, star-gauged and impressions taken.
	27¾			Rounds 17–60 inclusive; gun opened with difficulty by hand; no escape of gas.

PLATE I.

BREECH MECHANISM OF 3.2 INCH STEEL RIFLE

Fig. 2.

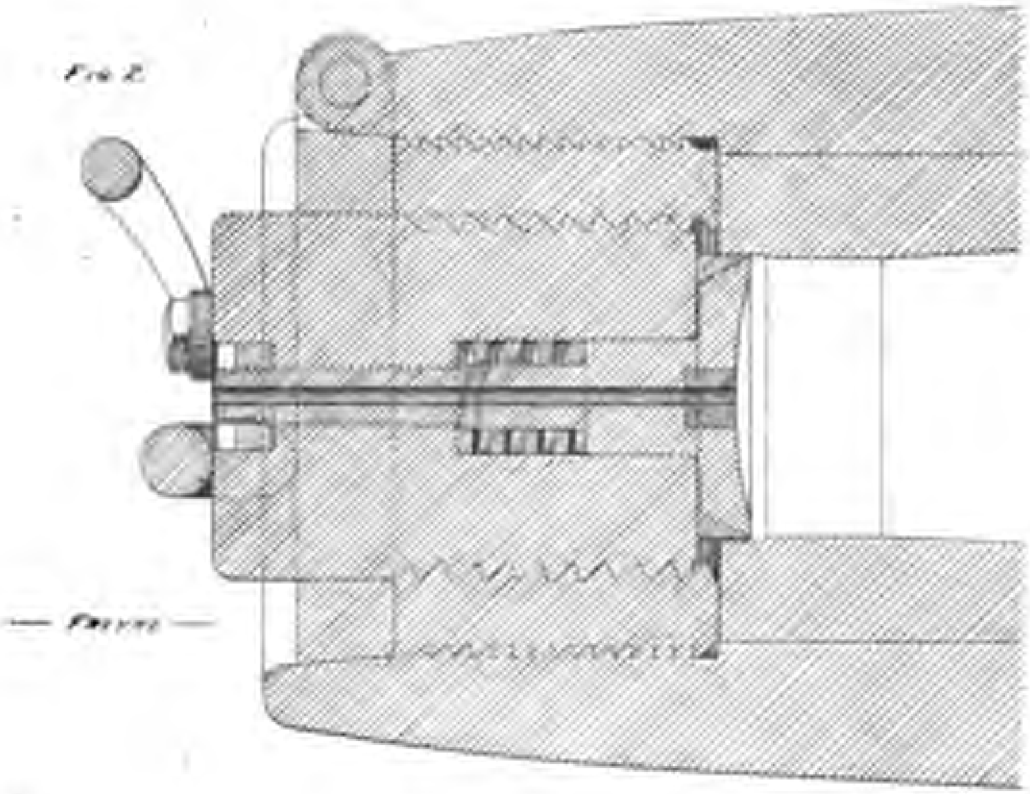
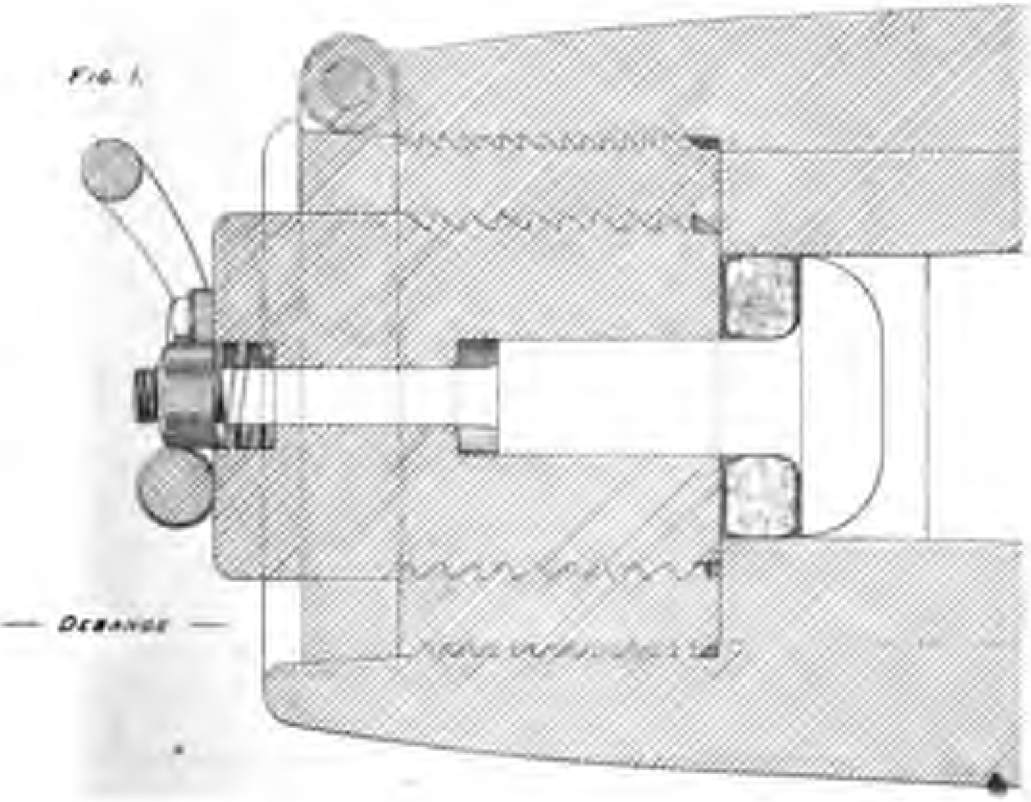


Fig. 1.



Appendix 14—1884.

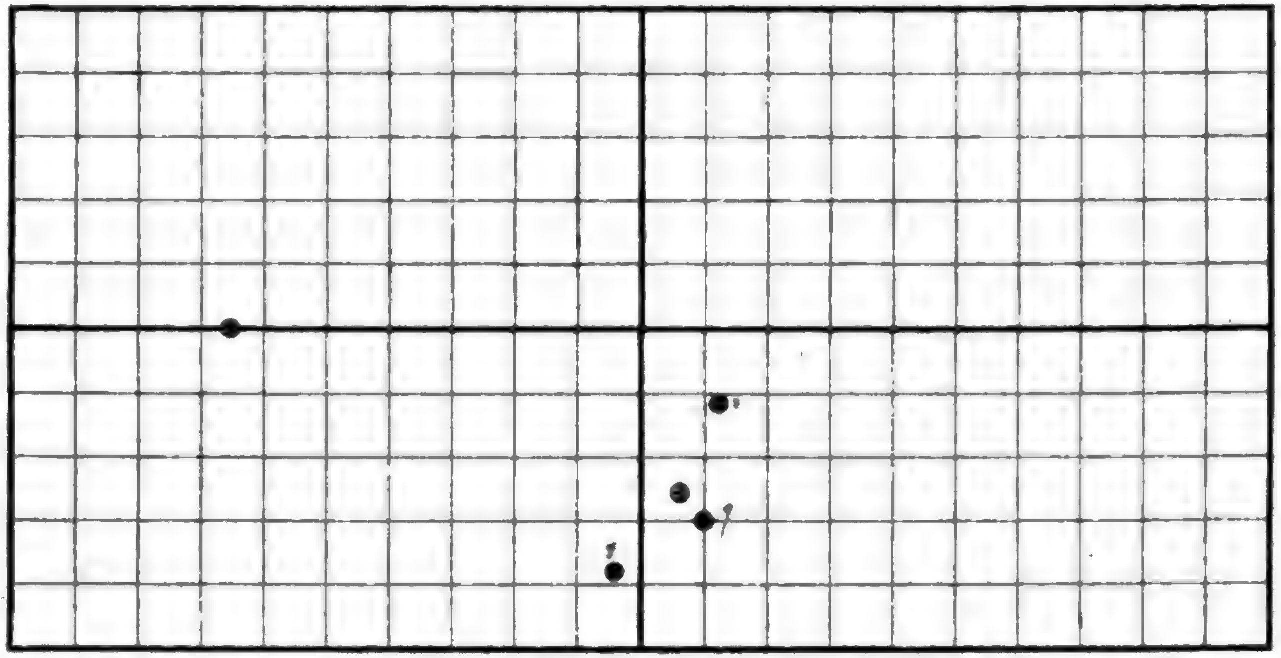
PLATE II.

TARGET RECORD of 3.2 B.L. Rifle (Steel)

July 11/84 AT SANDY HOOK, N. J.

Target One mile *from Gun.*

Number of shots fired, 3 *Direct hits,* 3 *Ricochet hits,* 0 *Misses,* 0



● *Center of impact.*

⊛ *Point aimed at.*

Target 10' × 40'

Mean vertical deviation from center of impact, 2.46

Mean horizontal deviation from center of impact, 1.33

Mean deviation from center of impact, 2.45

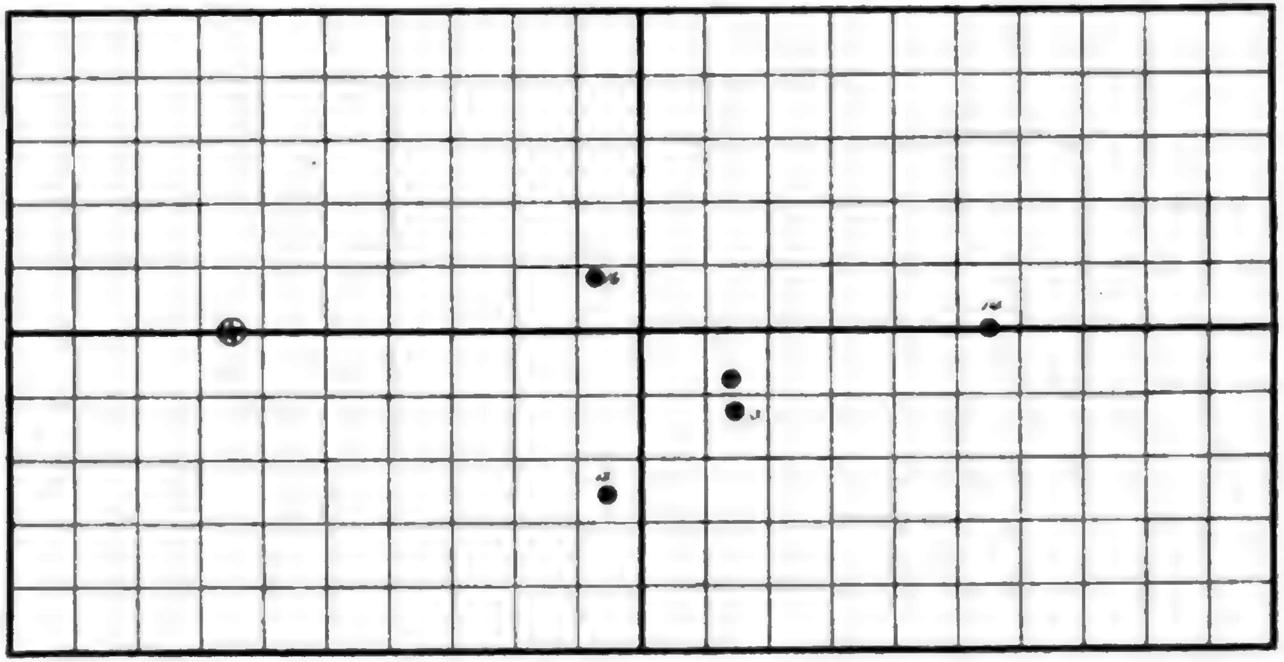
Wind 18 *miles per hour.*

TARGET RECORD of 3.2 B.L. Rifle (Steel)

July 16/84 AT SANDY HOOK, N. J.

Target One mile *from Gun.*

Number of shots fired, 5 *. Direct hits,* 4 *. Ricochet hits,* 0 *. Misses,* 1 *.*



● *Center of impact.*

⊛ *Point aimed at.*

Target 20' × 10'

Mean vertical deviation from center of impact, . 1.37

Mean horizontal deviation from center of impact, . 4.12

Mean deviation from center of impact, 4.75

Wind 7 *miles per hour.*

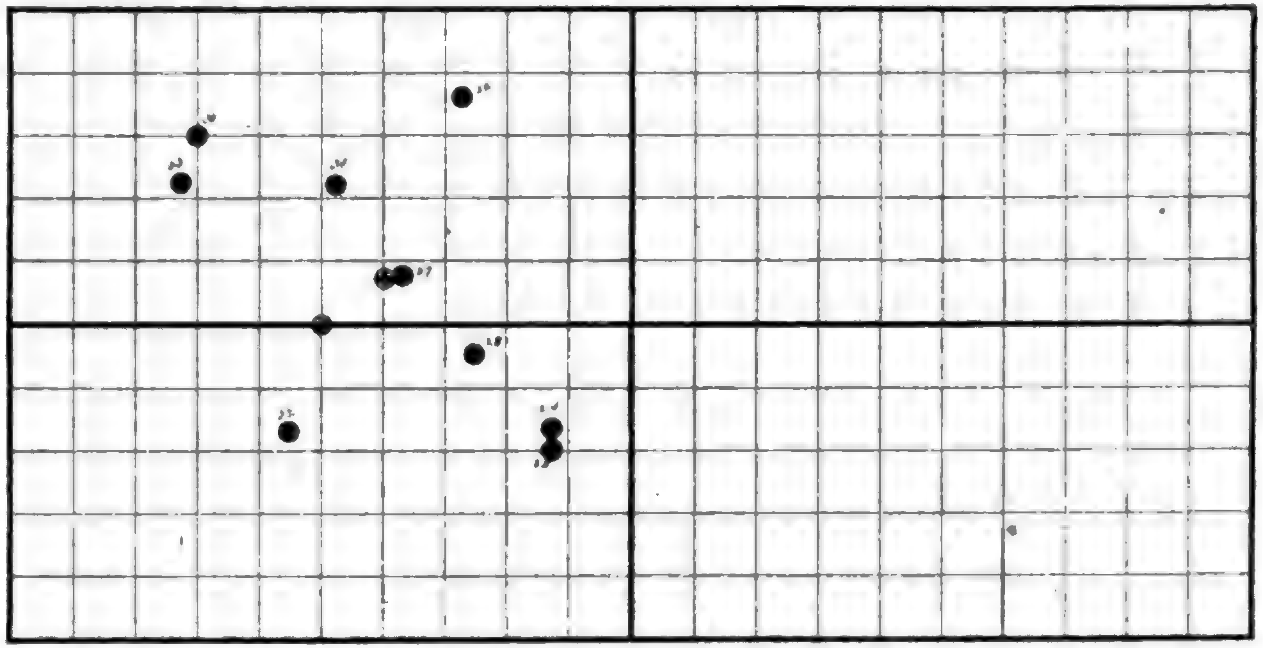
PLATE IV.

TARGET RECORD of 3.2 B.L. Rifle (Steel)

July 23/84 AT SANDY HOOK. N. J.

Target One mile *from Gun.*

Number of shots fired, 16 . *Direct hits,* 9 . *Ricochet hits,* 6 . *Misses,* 1 .



⊕ *Center of impact.*

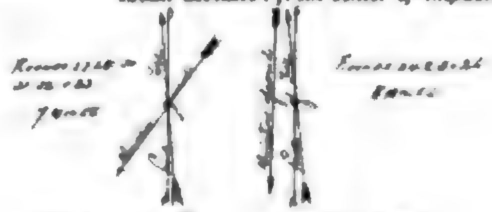
⊛ *Point aimed at.*

Mean vertical deviation from center of impact, .380

Mean horizontal deviation from center of impact, .378

Mean deviation from center of impact, .536

Target 10 = 40



Wind 7–8 *miles per hour.*

APPENDIX 15.

REPORT ON SOLID-BAND SHELL FOR 3.2-INCH BREECH-LOADING STEEL GUN, BY THE ORDNANCE BOARD.

(7 plates.)

A letter from the Chief of Ordnance, dated January 19, 1884, directed the Ordnance Board to work up a plan for a copper-banded projectile for the 3.2-inch field gun, and to have a few experimental ones made at Watertown Arsenal for trial. On February 5 the Board submitted a drawing showing a proposed shell with a band 0.35-inch wide, and requested that shell and bands might be furnished separately, that the proper position and dimensions of the latter might be determined by experiment. On May 2, 1884, fifty shell and one hundred bands were forwarded from Watertown Arsenal, and after a delay in preparing the gun for the new projectiles experiments commenced June 4, 1884.

The projectile (Plate I) is made of cast iron; has a cavity which will contain from five and a half to six ounces of musket powder, and is furnished with a base percussion-fuze. The head is an ogive, struck with a radius of one and one-half diameters; the body is cylindrical throughout, and the base is a plane intersecting the surface of the body. The band is made from a solid strip of copper, grooved on the side, which is to be in contact with the projectile. An annular groove is turned in the body of the projectile, the central element of the groove surrounding the center of percussion of the projectile, taken with reference to an axis situated in the plane of junction of the body and the head. This groove is undercut to form a dovetail. When the band has been cut to a proper length, the ends, planed down, form a scarf joint. The band is forced into place by screws, then hammered hard to force the inner edges into the undercut part of the groove, and afterwards turned down to the proper exterior diameter. The weight of the shell with bursting charge and fuze is thirteen pounds.

The experiment was commenced by firing a projectile with a band 0.35-inch wide and 3.31 inches in diameter into a sand butt, using a charge of 3 pounds of I. K. B. powder. The muzzle velocity was 1,517 feet, the pressure 30,500 pounds to the square inch. When the projectile was recovered the lands were molded sharply and smoothly in the band.

Three rounds, Nos. 43, 44, and 45 of the record, were fired at the mile target, and plotted as shown in Plate III.

A projectile with a band 0.5-inch wide was then fired into the butt with the same charge as before. The muzzle velocity was 1,503 feet, the pressure 31,000 pounds, and the lands were as well marked as before. Plate IV shows the target made at one mile with this projectile.

In these cases the front edge of the band only was chamfered.

The results of the first trial seemed to be in favor of the projectile with the broad band, as the mean vertical deviations, the most important ones in field guns, were less:

Two series of firings were then executed with the narrow and broad bands, having both the front and rear edges chamfered.

The first shot in this series (No. 52 of the record) fired with a narrow band projectile gave a muzzle velocity of 1,492 feet and 25,750 pounds pressure.

The target at a mile is shown in Plate V, the mean vertical deviation was 2.05 feet, the mean horizontal 3.35 feet.

The first shot in the second series (No. 63 of the record) gave a muzzle velocity of 1,501 feet and 26,500 pounds pressure. The diameter of the band was reduced from 3.31 to 3.30 inches.

The target at a mile is shown in Plate VI. The mean vertical deviation was 1.81 feet, the mean horizontal deviation was 1.53 feet, while a less elevation was required to reach the target, showing that this band gave for the same charge an increased accuracy and range. The superiority of the broad band was thus made manifest.

The trial was concluded by placing a narrow band in a groove not cut about the center of percussion above referred to, but so placed that the central element of the band was 0.825 of an inch in rear of the position first given to it, as shown in Plate II.

The target at a mile is shown in Plate VII. The mean horizontal deviation was 2.95 feet; the mean vertical 2.36 feet. Thus the result was inferior to that previously obtained with the narrow band, which in turn was inferior to that obtained with the broad band.

A shell burst in a wooden box gave the following results:

Bursting charge, 6 ounces; weight of shell, 12.6 pounds; weight recovered, 12.4 pounds; 39 fragments; 18 fragments under 1 ounce weight; 21 fragments over 1 ounce weight; 19 fragments over 2 ounces weight.

Considering fragments over 1 ounce weight effective, there resulted 21 effective fragments. The pieces were fairly uniform in size and the shell appeared to be equally strong throughout.

SUMMARY.

	Mean velocity.	Mean pressure per square inch.	Mean deviation.	
			Horizontal.	Vertical.
	Feet.	*Pounds.*	*Feet.*	*Feet.*
Narrow band, 0.35-inch wide, surrounding center of percussion	1504.5	28,208	3.35	2.05
Broad band, 0 5-inch wide, surrounding center of percussion	1502	32,333	1.53	1.81
Narrow band, 0.35-inch wide, 0.825-inch in rear of center of percussion	1490	24.750	2.95	2.36

In all cases a clear smooth flight was observed. The mean deviations are taken from Plates V, VI, and VII. The range was, accurately speaking, 87 yards less than a mile.

The recommendation of the Board is, that shell for the 3.2 inches converted breech-loading rifles be supplied with copper band 0.5 inch wide, arranged as shown in the accompanying drawing.

The 3.2-inch converted guns now in service were chambered for the Hotchkiss shot. If the shell above referred to are issued, a slight change will be required in that part of the bore where the band bears. The counter bore in rear of the lands and the diameter must be increased slightly. Templates of brass can be prepared at Sandy Hook and sent to the establishments where the guns in service are to be changed.

The base fuzes were furnished by Hotchkiss & Co., of Paris. They were intended for use against light armor, and are unsuitable for service in the field against obstacles of slight resisting power. It is thought that a small number of high-resistance fuzes should be supplied to each battery, and that more sensitive fuzes should be furnished for ordinary use.

In a letter from Mr. Hotchkiss to the Chief of Ordnance, dated Paris, April 8, 1884, which letter was referred to the Ordnance Board for information, it is stated that modified base fuzes would be sent to New York arsenal, but as yet they have not been received.

Firing and star gauge records accompany this report, and give full details of the experiments with solid band shell.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. MCKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Star-gauging of 3.2-inch B. L. rifle, No. 914.

Inches from muzzle.	June 4, 1884.—Diameter after 39 rounds.	June 6, 1884.—Diameter after 62 rounds.	June 17, 1884.—Diameter after 84 rounds.	Inches from muzzle.	June 4, 1884.—Diameter after 39 rounds.	June 6, 1884.—Diameter after 62 rounds.	June 17, 1884.—Diameter after 84 rounds.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
57	3. 195	....	.....	28	3. 195	3. 199	3. 199
56	3. 195	....	.....	27	3. 195	3. 199	3. 199
55	3. 195	....	.....	26	3. 195	3. 199	3. 199
54	3. 195	....	.....	25	3. 195	3. 199	3. 199
53	3. 195	3. 224	3. 229	24	3. 195	3. 199	3. 199
52	3. 195	3. 217	3. 225	23	3. 195	3. 198	3. 199
51	3. 195	3. 215	3. 224	22	3. 195	3. 198	3. 199
50	3. 195	3. 214	3. 222	21	3. 195	3. 197	3. 199
49	3. 195	3. 215	3. 219	20	3. 195	3. 197	3. 199
48	3. 195	3. 213	3. 219	19	3. 195	3. 196	3. 199
47	3. 195	3. 204	3. 209	18	3. 195	3. 196	3. 199
46	3. 195	3. 04	3. 208	17	3. 195	3. 196	3. 198
45	3. 195	3. 203	3. 206	16	3. 195	3. 196	3. 198
44	3. 195	3. 202	3. 205	15	3. 195	3. 196	3. 198
43	3. 195	3. 202	3. 204	14	3. 195	3. 196	3. 197
42	3. 194	3. 201	3. 204	13	3. 195	3. 196	3. 197
41	3. 194	3. 201	3. 204	12	3. 195	3. 196	3. 197
40	3. 194	3. 201	3. 203	11	3. 195	3. 196	3. 196
39	3. 194	3. 201	3. 203	10	3. 195	3. 196	3. 196
38	3. 194	3. 201	3. 203	9	3. 195	3. 196	3. 196
37	3. 194	3. 200	3. 203	8	3. 195	3. 195	3. 196
36	3. 194	3. 200	3. 203	7	3. 195	3. 195	3. 196
35	3. 193	3. 200	3. 203	6	3. 195	3. 195	3. 196
34	3. 193	3. 206	3. 203	5	3. 195	3. 195	3. 196
33	3. 193	3. 200	3. 203	4	3. 195	3. 195	3. 196
32	3. 194	3. 199	3. 200	3	3. 195	3. 195	3. 196
31	3. 195	3. 199	3. 200	2	3. 195	3. 195	3. 196
30	3. 195	3. 199	3. 200	1	3. 195	3. 195	3. 196
29	3. 195	3. 199	3. 200				

Record of firing with 3.2-inch breech-loading rifle No. 914,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore.	Instrumental velocity, 93 feet.	Recoil.	Wind, strength and direction.	
			Kind.	Weight.	Kind.	Weight.						
		1884.		Lbs.		Lbs.	° '	Lbs.	Feet.	Feet.		
Barometer, 30.004; thermometer, 83; humidity, 43.	40	June 4	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Solid band, experimental shell: Narrow band, beveled in front only. Diameter, 3".31; width, 0".35.	13	0 00	30, 500	1, 501	7. 75	From front and right 3°.	5 miles an hour.
Barometer, 30.134; thermometer, 75.3; humidity, 60.	41	June 5		3		13	3 13	29, 000	......	12. 50		12 miles an hour.
	42	June 5		3		13	3 5	26, 500	......	13. 50		
	43	June 5		3		13	2 55	29, 250	......	13. 50		
	44	June 5		3		13	3 00	26, 500	......	10. 50		
	45	June 5		3		13	3 00	27, 500	......	12. 50		
	46	June 5		3	Solid band, experimental shell: Wide band, beveled in front only. Diameter, 3".31; width, 0".50.	13	0 00	31, 000	1, 487	13. 00		
Barometer, 30.103; thermometer, 79.7; humidity, 45.	47	June 5		3		13	3 00	28, 250	......	9. 00		20 miles an hour.
	48	June 5		3		13	3 00	25, 000	......	12. 50		
	49	June 5		3		13	3 00	28, 000	......	11. 50		
	50	June 5		3		13	3 00	46, 000	......	13. 50		
	51	June 5		3		13	3 00	35, 750	......	12. 50		
Barometer, 30.156; thermometer, 72.2; humidity, 66.	52	June 6		3	Solid band, experimental shell: Narrow band, beveled in front and rear. Diameter, 3".30; width, 0".35.	13	0 00	25, 750	1, 476	7. 50		16 miles an hour.
	53	June 6		3		13	3 00	......	......	6. 00		
	54	June 6		3		13	3 00	......	......	5. 75		
	55	June 6		3		13	3 00	......	......	6. 50		
	56	June 6		3		13	3 00	......	......	6. 00		
	57	June 6		3		13	3 00	......	......	6. 00		
	58	June 6		3		13	3 00	......	......	6. 50		
	59	June 6		3		13	3 00	......	......	6. 50		
	60	June 6		3		13	3 00	......	......	6. 00		
	61	June 6		3		13	3 00	......	......	6. 00		
	62	June 6		3		13	3 00	......	......	6. 25		

at Sandy Hook, N. J., from June 4, to June 16, 1884.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Vertical.		Horizontal.		Vertical.		Horizontal.		
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
This gun had been previously fired 30 rounds as a 3″ converted breech-loading rifle; after which it was sent to the West Point Foundery Association, and converted in to a 3″.20 breech-loading rifle.								
Fired into sand butt.								
Fired at mile target; sighting shots.								
Good flights.								
....	8.00	3.00	....	....	9.42	0.17	....	Fired at mile target. Target 20′ × 40′, made of 1-inch spruce boards.
6.00	....	6.00	....	4.58	....	3.17	....	
6.26	....	....	0.51	4.84	....	....	3.34	
12.26	8.00	9.00	0.51	9.42	9.42	3.34	3.34	Mean vertical deviation from center of impact, 6′.28.
4.26÷3=1.42		8.49÷3=2.83		18.84÷3=6.28		6.68÷3=2.23		Mean horizontal deviation from center of impact, 2′.23. Mean deviation from center of impact, 6′.67.
Fired into sand butt.								
Good flights.								
4.00	....	....	....	....	0.10	....	0.87	Fired at mile target. Target 20′ × 40′, made of 1-inch spruce boards.
9.00	....	7.35	....	4.90	....	6.48	....	
4.50	....	....	....	0.40	....	....	0.87	
....	....	....	4.00	....	4.10	....	4.87	
3.00	....	1.00	....	....	1.10	0.13	....	
20.50	....	8.35	4.00	5.30	5.30	6.61	6.61	Mean vertical deviation from center of impact, 2′.12.
20.50÷5=4.10		4.35÷5=0.87		10.60÷5=2.12		13.22÷5=2.64		Mean horizontal deviation from center of impact, 2′.64. Mean deviation from center of impact, 3′.39.
Fired into sand butt. Good flights.								
....	3.75	12.00	....	....	2.90	7.06	....	Fired at mile target. Target 20′ × 40′, made of 1-inch spruce boards.
....	....	....	6.67	0.85	....	....	11.61	
....	....	5.50	.....	0.85	....	0.56	....	
....	....	5.16	....	0.85	....	0.22	....	
....	1.00	6.25	....	....	0.15	1.31	....	
0.25	....	1.75	....	1.10	....	....	3.19	
5.75	....	7.00	....	6.60	....	2.06	....	
....	3.25	5.16	....	....	2.40	0.22	....	
....	1.50	10.25	....	....	0.65	5.31	....	
....	5.00	3.00	....	....	4.15	....	1.94	
6.00	14.50	56.07	6.67	10.25	10.25	16.74	16.74	Mean vertical deviation from center of impact, 3′.05.
8.50÷10=0.85		49.40÷10=4.94		20.50÷10=2.05		33.48÷10=3.35		Mean horizontal deviation from center of impact, 3′.35. Mean deviation from center of impact, 3′.93. Gun washed out, examined, and star-gauged.

Record of firing with 3.2-inch breech-loading rifle No. 914,

	Number of fire.	Time	Powder.		Projectiles.		Elevation.	Pressure, per square inch of bore.	Instrumental velocity, 93 feet.	Recoil.	Wind, strength and direction.
			Kind.	Weight.	Kind.	Weight.					
		1884.		*Lbs.*		*Lbs.*	° ′	*Lbs.*	*Feet.*	*Feet.*	
Barometer, 29.988; thermometer, 66.8; humidity, 85.	63	June 12	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	Solid band, experimental: Band, 3″.30 diameter; width, 0″.5; beveled front and rear.	13	0 00	26,500	1,485	7.00	....
	64	June 12		3		13	3 00	......	......	5.33	....
	65	June 12		3		13	3 00	......	......	5.40	
	66	June 12		3		13	2 50	......	......	6.83	From front and left 87°, 4 miles an hour.
	67	June 12		3		13	2 50	......	......	5.50	
	68	June 12		3		13	2 50	......	......	5.75	
	69	June 12		3		13	2 50	......	......	5.58	
	70	June 12		3		13	2 50	......	......	5.50	
	71	June 12		3		18	2 50	......	......	5.25	
	72	June 12		3		13	2 50	......	......	5.75	
	73	June 12		3		13	2 50	......	......	5.50	
Barometer, 30.189; thermometer, 79.8; humidity, 33.	74	June 16		3	Solid band, experimental: Band, 3″.30 diameter; width, 0″.35; beveled front and rear; band ¾″ from base of shell.	13	0 00	24,750	1,474	6.16	....
	75	June 16		3		13	3 00	......	......	5.50	....
	76	June 16		3		13	3 00	......	......	6.00	From rear and right 87°, 12 miles an hour.
	77	June 16		3		13	3 00	......	......	6.83	
	78	June 16		3		13	3 00	......	......	7.00	
	79	June 16		3		13	3 00	......	......	7.16	
	80	June 16		3		13	3 00	......	......	8.00	
	81	June 16		3		13	3 00	......	......	6.83	
	82	June 16		3		13	3 00	......	......	6.83	
	83	June 16		3		13	3 00	......	......	7.16	
	84	June 16		3		13	3 00	......	......	6.16	

at Sandy Hook, N. J., from June 4 *to June* 16, 1884—Continued.

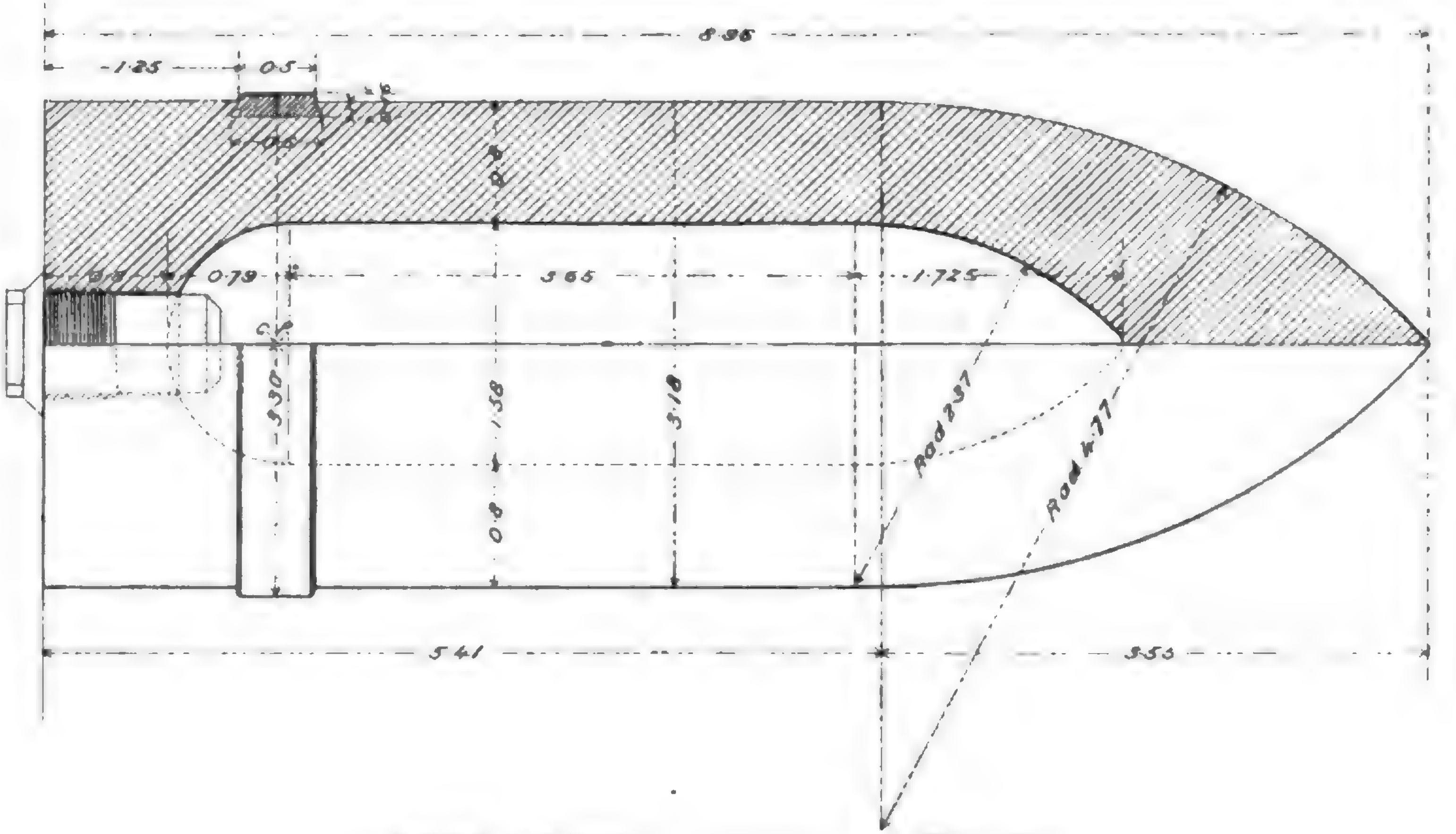
	Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
	Vertical.		Horizontal.		Vertical.		Horizontal.		
	Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
Fired into sand butt.									
Sighting shot.									
Good flights.	....	2.00	9.00	....	1.81	....	2.78	....	Fired at mile target. Target 20′ × 40′, made of 1-inch spruce boards.
	....	6.66	5.00	....	....	2.85	....	1.22	
	....	2.50	5.50	....	1.81	....	....	0.72	
	....	2.82	5.00	....	0.99	....	....	1.22	
	....	2.00	5.50	....	1.81	....	....	0.72	
	....	4.25	4.00	....	....	0.44	....	2.22	
	....	2.50	7.76	....	1.81	....	1.54	....	
	....	7.75	8.00	....	....	3.94	1.78	....	
	....	30.48	49.76	....	7.23	7.23	6.10	6.10	Mean vertical deviation from center of impact, 1′.81. Mean horizontal deviation from center of impact, 1′.53. Mean deviation from center of impact, 2′.37.
	30.48+8=3.81		49.76+8=6.22		14.46+8=1.81		12.20+8=1.53		
Fired into sand butt..............................									
Sighting shot..............................									
Good flights.	....	4.75	....	....	....	3.37	2.57	....	Fired at mile target. Target 20′ × 40′, made of 1-inch spruce boards.
	...	1.75	......	5.75	....	0.37	....	3.18	
	2.83	....	....	7.65	4.21	....	....	5.08	
	....	6.00	5.00	....	....	4.62	7.57	....	
	.	3.00	....	4.00	....	1.62	....	1.43	
	2.75	....	....	3.23	4.13	....	....	0.66	
	0.75	....	....	....	2.13	....	2.57	....	
	....	1.25	....	5.50	0.13	....	....	2.93	
	....	2.00	....	2.00	....	0.62	0.57	....	
	6.33	18.75	5.00	28.13	10.60	10.60	13.28	13.28	Mean vertical deviation from center of impact, 2′.36. Mean horizontal deviation from center, of impact, 2′.95. Mean deviation from center of impact, 3′.84.
	12.42+9=1.38		23.13+9=2.57		21.20+9=2.36		26.56+9=2.95		Gun washed out, examined, and star-gauged. The powder-chamber, as well as the rear part of bore, has enlarged since the 40th round from [illegible] to [illegible] of an inch.

Round 40, mounted on wooden carriage with rope brake. Rounds 41–51, inclusive: rope brake replaced by Buffington brake; trail and stock of carriage badly cracked. Rounds 52–73, inclusive: mounted on iron carriage with rope brake; the trail was badly bent. Rounds 74–81: rope brake replaced by Buffington brake. Round 52: after round 41 the outside joint, between the steel receiver and wrought-iron body, was found to have opened, and gas was escaping along the steel plug which had been inserted by the West Point Foundery Association to fill up the old vent bushing; the steel plug was then replaced by a copper one; after round 52 the opening between steel and wrought iron was found to be 0.011 inch, and increased subsequently but slightly. The targets, reported as being distant one mile, were really 87 yards short, in consequence of the position in which it was necessary to place the gun.

Shell exploded; bursting charge, 6 ounces; weight of shell, 12.6 pounds; weight of shell recovered, 12.4 pounds; 39 fragments, 18 under 1 ounce, 21 over 1 ounce, 19 over 2 ounces.

PLATE I.

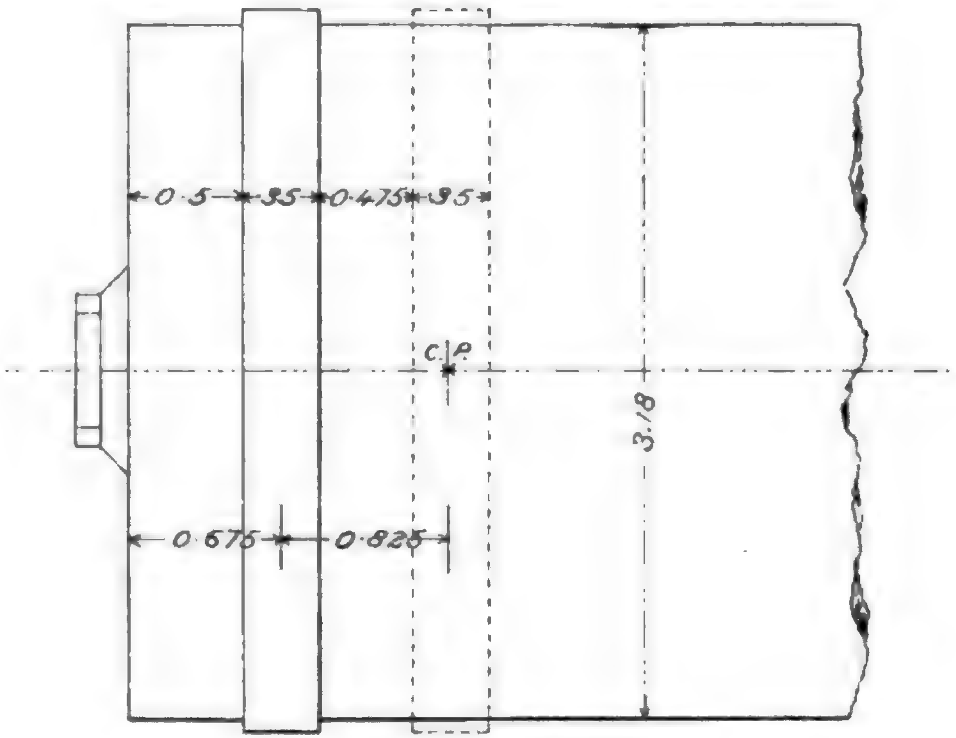
SHELL FOR 3·2 INCH B.L. RIFLE



Weight of Shell	12·67 lbs.
" Charge	·33 "
Total Weight of Shell	13·00 "

Appendix 15—1884.

SKETCH SHOWING DIFFERENT POSITIONS OF BAND

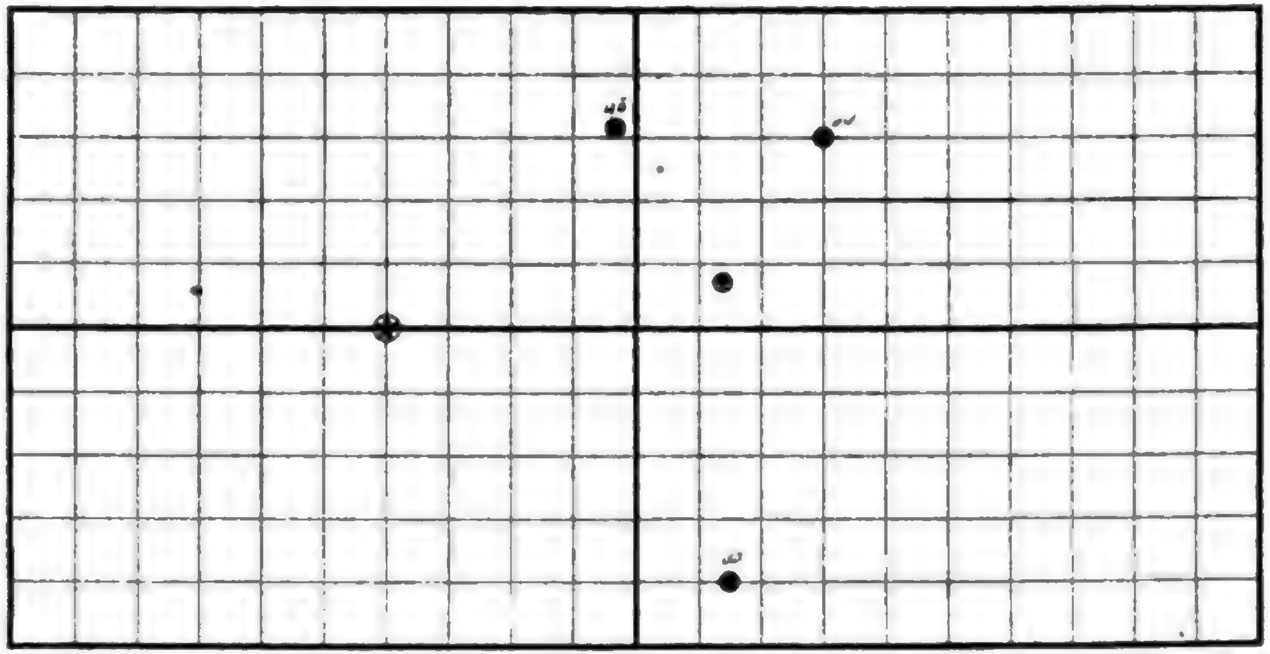


TARGET RECORD of 12 B.L. Rifle # 914

June 5. 1884 AT SANDY HOOK. N. J.

Target One Mile *from Gun.*

Number of shots fired, 5 *. Direct hits,* 5 *. Ricochet hits,* 0 *. Misses,* 0 *.*



⊕ *Center of impact.*

⊕ *Point aimed at.*

Target [illegible] × 30'

Mean vertical deviation from center of impact, 6.28.

Mean horizontal deviation from center of impact, 2.23.

Mean deviation from center of impact, 6.67.

Wind 19 *miles per hour.*

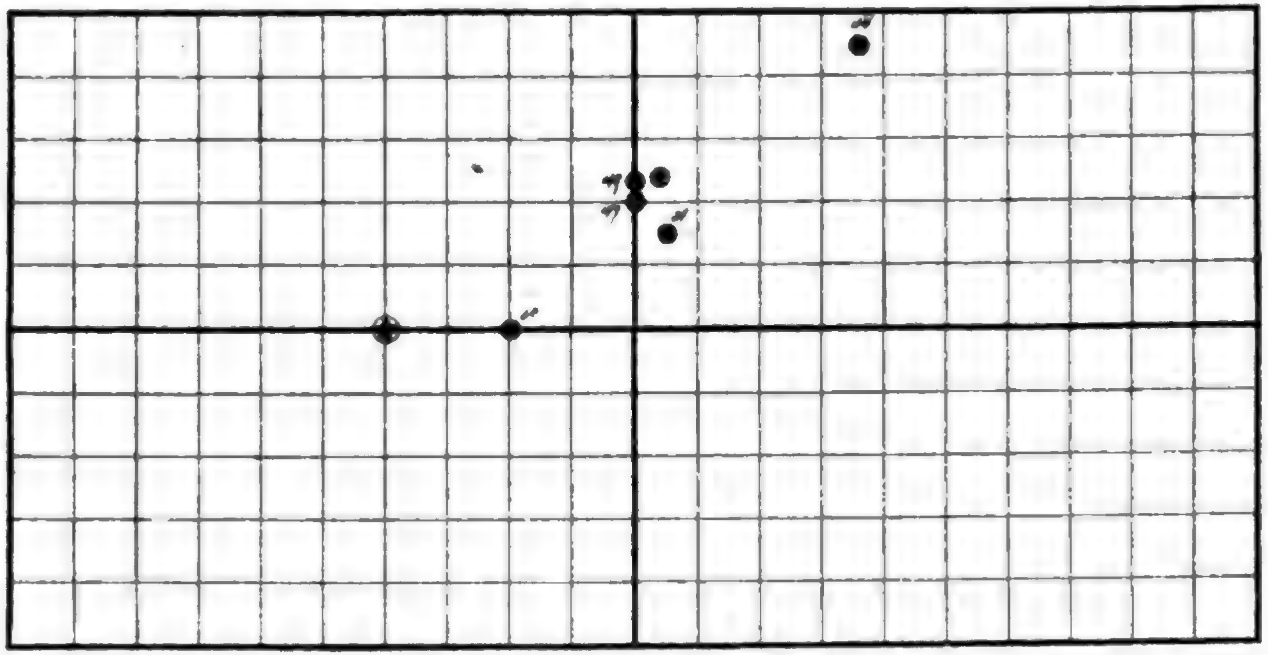
PLATE IV.

TARGET RECORD of 3.2 B.L. Rifle #914

June 5/84 AT SANDY HOOK. N. J.

Target One mile *from Gun.*

Number of shots fired, 5 *Direct hits,* 5 *Ricochet hits,* 0 *Misses,* 0



⊕ *Center of impact.*

⊕ *Point aimed at.*

Target 10' × 40'

Mean vertical deviation from center of impact. 2.12.

Mean horizontal deviation from center of impact. 2.64.

Mean deviation from center of impact. 3.39.

Wind 2.0 *miles per hour.*

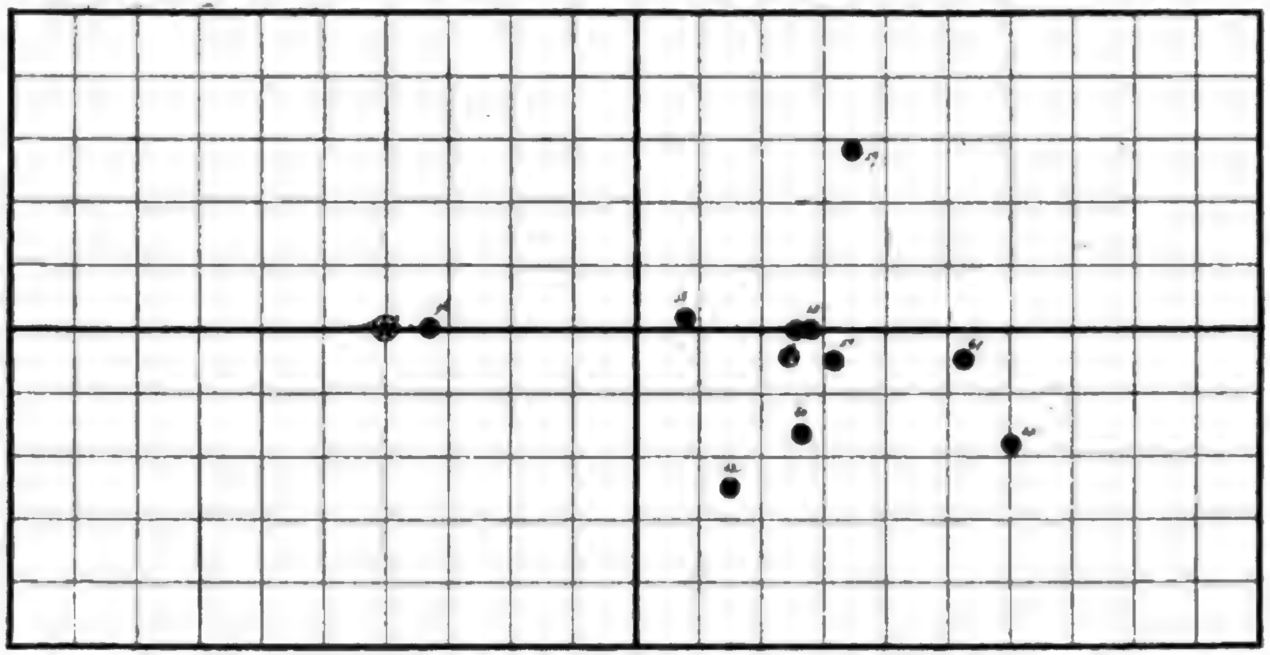
Appendix 15—1884.

TARGET RECORD of 3".2 B.L. Rifle #9

June 6/84 AT SANDY HOOK. N. J.

Target One mile *from Gun.*

Number of shots fired, 10 . *Direct hits,* 10 . *Ricochet hits,* 0 . *Misses,* 0 . . .



● *Center of impact.*

⊛ *Point aimed at.*

Target 10' × 10'

Mean vertical deviation from center of impact, 2.15

Mean horizontal deviation from center of impact, 3.35

Mean deviation from center of impact, 3.98

Wind 16 *miles per hour.*

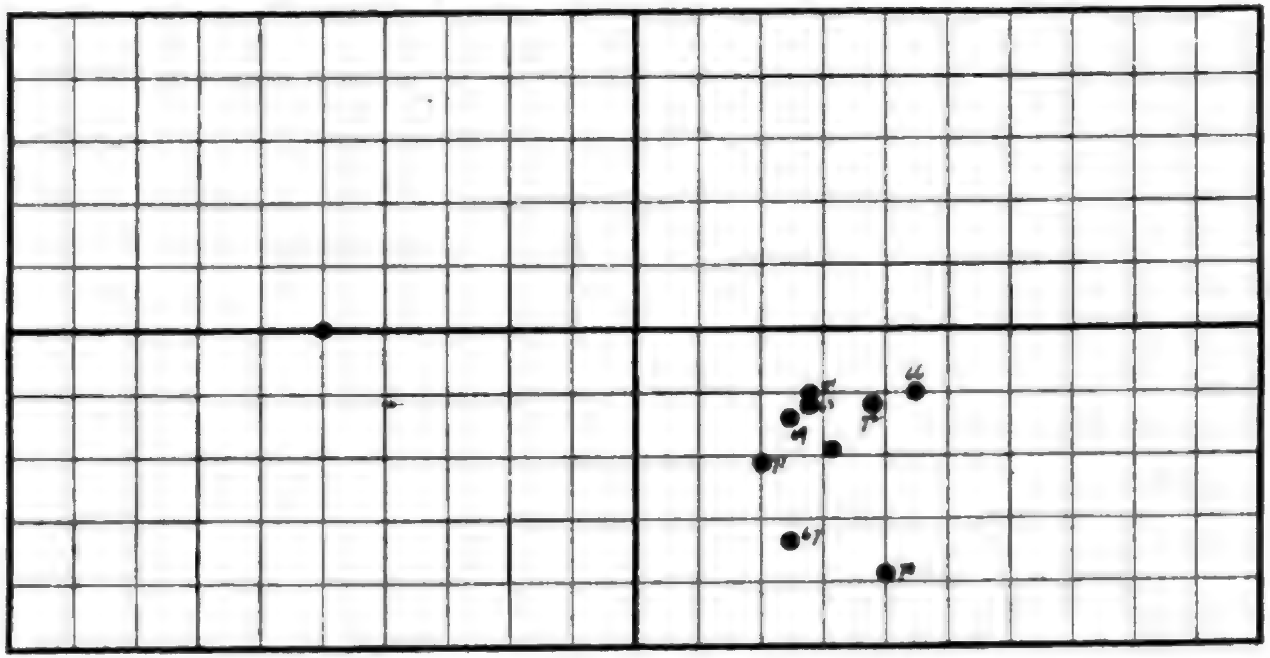
Appendix 15—1884.

TARGET RECORD of 32 B.L. Rifle #914

June 17/84 AT SANDY HOOK. N. J.

Target One mile *from Gun.*

Number of shots fired, 8 *. Direct hits,* 8 *. Ricochet hits,* 0 *. Misses,* 0



● *Center of impact.*

⊛ *Point aimed at.*

Target 10' × 10'

Mean vertical deviation from center of impact, 1.81

Mean horizontal deviation from center of impact, 1.53

Mean deviation from center of impact, 2.37

Wind 4 *miles per hour.*

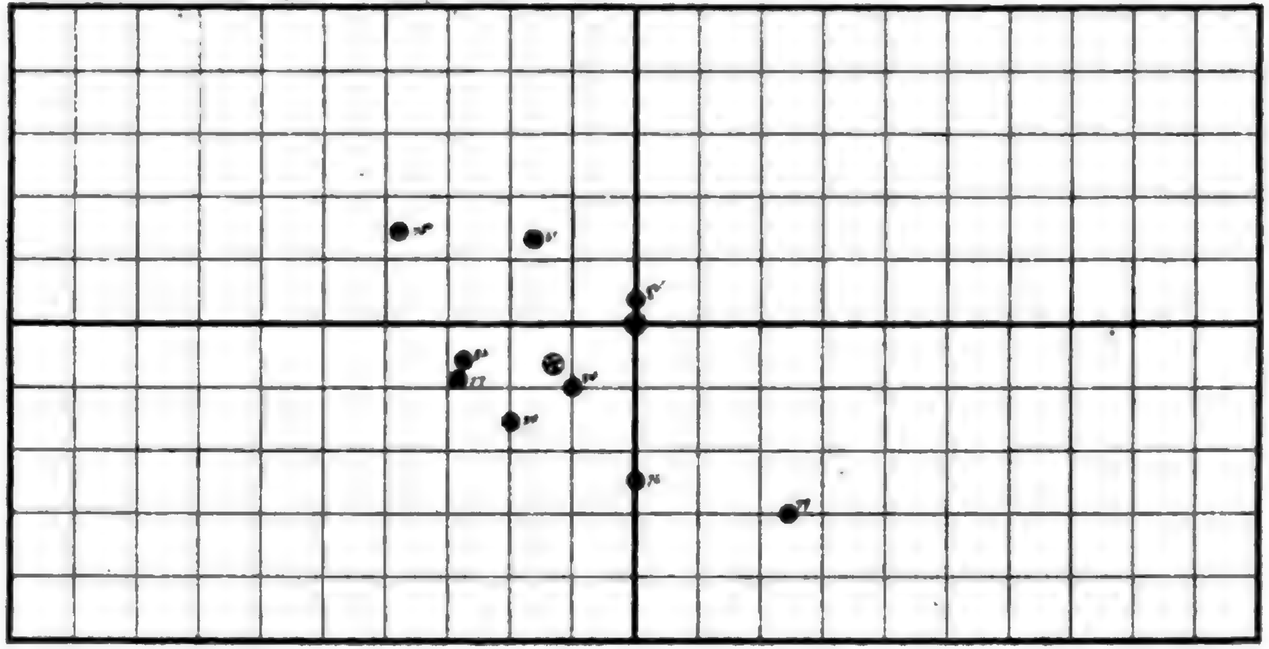
Appendix 15—1884.

TARGET RECORD of 3.2 B.L. Rifle No. 4

June 16/84 AT SANDY HOOK, N. J.

Target One mile *from Gun.*

Number of shots fired, 9 . *Direct hits,* 9 . *Ricochet hits,* 0 . *Misses,* 0 .



⊕ *Center of impact.*

⊛ *Point aimed at.*

Target 20′ × 40′

Mean vertical deviation from center of impact, 2.36

Mean horizontal deviation from center of impact, 2.95

Mean deviation from center of impact, 3.84

Wind 12 *miles per hour.*

APPENDIX 16.

REPORT ON SHRAPNEL AND SHELL FOR 3.2-INCH GUN BY THE ORDNANCE BOARD.

(2 plates.)

On June 7, 1883, the Board forwarded to the Bureau designs for a shrapnel and shell for a 3.2-inch breech-loading rifle, with a request for authority to procure 25 of each for trial at Sandy Hook.

These projectiles were to be made with the Hotchkiss band and to be arranged so as to use a time-fuze at the point and a percussion-fuze at the base. Authority was granted, and the projectiles were ordered from Messrs. Hotchkiss' Sons, Bridgeport, Conn.

The shrapnel were not ordered to be made exactly in accordance with the design forwarded to the Bureau; the walls were to be thicker, so that they might be reduced as experiment would justify.

On December 4, 1883, the trials commenced, when 2 shrapnel and 3 shell were fired to obtain pressures and velocities, and at the same time ascertain whether the point fuze would work, the base-fuze hole being closed by a solid plug. The weights of the shrapnel and shell were respectively 15 and 13 pounds, and the charge of powder in both cases was 3 pounds of I.K.B. powder. The average velocities and pressures were for the shrapnel 1,389 feet and 23,750 pounds, and for the shell 1,475 feet and 23,500 pounds. The shrapnel in this case corresponded to the drawing sent to Messrs. Hotchkiss' Sons.

Three of the shrapnel were then reamed out to correspond to the thickness of the walls on design sent to Bureau and fired on December 6, 1883, when 2 out of the 3 broke up in gun.

This result indicated that the walls of the shrapnel could not be safely reduced to the dimensions of the original design, and it was consequently concluded to retain the same thickness as ordered from Messrs. Hotchkiss' Sons.

It was thought, however, that the weight of the shrapnel was too great, and that it was important to have the weights of the shell and shrapnel as nearly equal as possible, so that the times of bursting of each would correspond in range for the same length of time-fuze. In order to effect this it was concluded to reduce the length of the cylindrical part, and 2 were prepared in this way; one with the head or cap made of brass pinned on as before, and the other with a cast-iron cap screwed on. These were fired on February 20, 1884, with good results as far as the strength of the shrapnel was concerned. Five others were prepared by the same reduction in length; four of them with brass caps, two of which were pinned on and two screwed on, and one with cast-iron cap screwed on. These were fired on March 5 and gave good results. Six more were prepared of the same length, with cast-iron caps screwed to the body of the shrapnel, and were fired March 12 and gave good results

CONCLUSIONS.

The Board is of opinion from the results thus obtained that the dimensions of the shrapnel for a 3.2-inch rifle should be as given in the drawing herewith forwarded. The brass caps are preferred to the cast-iron ones, for the reason that the latter are liable to have blow-holes in them from such thin castings, and screwing on is thought to be better than the use of pins.

The dimensions of the shell as shown in the drawing forwarded to the Ordnance Office, February 5, 1884, are also recommended. No firings have been made with these projectiles yet to test the base fuze, but it is recommended that both projectiles be provided with point time-fuze and base percussion-fuze.

The dimensions of the shrapnel are given for the Hotchkiss band, but it is not thought that any variation will be made except to substitute an ordinary copper band for the Hotchkiss.

The dimensions and location of this band will be determined as soon as the Board has the 3-inch gun altered authorized by indorsement on Board letter of March 13, 1884. This report is made in advance of complete experiments, so as to give as much information as possible in answer to Bureau letter of July 28, 1883.

The firing records are herewith inclosed.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 3.20-inch breech-loading rifle No. 774, chambered.

	Number of fire.	Time.	Powder.		Projectile.			Elevation.	Pressure, per square inch of bore.	Instrumental velocity, 89 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Weight.	Kind.		Weight.					
		1883.		Lbs. oz.			Lbs. oz.	° ′	′	Ft.	Ft.	
Barometer, 30.350; thermometer, 31; humidity, 68.	850	Dec. 4	Du Ponts I. K. B. Density, 1.725; granulation, 2,200.	3 0	Hotchkiss.	Shell....	13 0	3 30	22,500	1473	6.02	From rear and left 1°, 2 miles an hour.
	851	Dec. 4		3 0		Shrapnel	15 0	3 30	23,000	1386	7.00	
Barometer, 30.233; thermometer, 50; humidity, 52.	852	Dec. 4		3 0		Shell	13 0	3 30	24,500	1478	6.02	From front and right 46°, 8 miles an hour.
	853	Dec. 4		3 0		Shrapnel	15 0	4 30	24,500	1392	7.83	
	854	Dec. 4		3 0		Shell.....	13 0	4 30	22,500	1480	6.75	
Barometer, 30.376; thermometer, 41; humidity, 82.	855	Dec. 6		3 0		Shrapnel. 175	15 4	4 30	26,500	....	7.00	From rear and left 46°, 10 miles an hour.
	856	Dec. 6		3 0		Shrapnel. 183	15 4	4 30	24,500	....	7.52	
	857	Dec. 6		3 0		Shrapnel. 186	15 4	4 30	24,500	....	7.20	
		1884.										
Barometer, 29.756; thermometer, 37.7; humidity, 46.	871	Feb. 20		3 0	Hotchkiss shrapnel.		13 0	5 00	25,500	....	7.00	From rear and right 87°, 48 miles an hour.
	872	Feb. 20		3 0	....do.........		13 0	8 00	23,500	....	7.00	
Barometer, 30.319; thermometer, 29; humidity, 88.	874	Mar. 5		3 0	Hotchkiss shrapnel.		13 8	3 00	......	....	6.50	From front and left 40°, 20 miles an hour.
	875	Mar. 5		3 0			13 10	2 45	......	....	8.00	
	876	Mar. 5		3 0			13 8	2 45	......	..	7.07	
	877	Mar. 5		3 0			13 8	2 30	......	....	8.83	
	878	Mar. 5		3 0			13 8	2 00	....	....	8.58	

at Sandy Hook, N. J., from December 4, 1883, to March 5, 1884.

Time of bursting.		Distance from muzzle of gun in yards to point of bursting.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Seconds.			
1	Fired over water.	Lost.	Time-fuze set to explode at 328 yards. The shrapnel used in rounds 851 and 853 were bored out so as to have an interior diameter of 2 $\frac{1}{16}$ inches and contained a bursting charge of 1¾ ounces of musket powder, which is included in the weight given of 15 pounds. Contained 115 lead balls—32 to the pound. The shell used in rounds 850, 852, and 854 contained a bursting charge of 8¾ ounces, which is included in the weight given of 13 pounds. The shrapnel used in rounds 855, 856, and 857 were made in accordance with the drawing furnished—the number of balls contained in each one being written under the word shrapnel in the column headed projectile; these also contain a bursting charge of 1¾ ounces musket powder.
0¾		195	
6½		2,055	Time-fuze set to explode at 1,094 yards.
3½		1,153	
3		1,120	
....		....	Broke up in gun ...
3½		....	
....		....	Broke up in gun ...
....		....	Fired over water. Krupp time-fuze set to explode at 1,094 yards. Shrapnel probably did not break up or explode.
....	....	....	Fired over water. Krupp time-fuze set to explode at 1,094 yards. Shrapnel did not explode. Struck water in 11½ seconds. The shrapnel used in round 871 contained a bursting charge of 1¾ ounces musket powder and 107 lead balls, 32 to the pound, the weight of both bursting charge and balls being included in the weight given of 13 pounds. The cap of this shrapnel was made of brass. The shrapnel used in round 872 same as one used in round 871 with the exception that the cap was made of cast iron instead of brass, and both differed from those used in rounds 851, and following, in that the caps were screwed to instead of being pinned to the body of the shrapnel.
Time to bursting point.			
3¼	....	....	Fired at 3 targets in column 1st 1,100 yards, 2d 1,150 yards, and 3d 1,200 yards from gun. 1st and 2d targets 39' × 6', 3d target 52' × 6', made of 1-inch spruce boards. Krupp time-fuze set to explode at 1,094 yards. Burst in air 100 yards in front of target, about 50 feet above ground. Krupp time-fuze set to explode at 1,094 yards. Did not explode. Struck ground 118 paces beyond last target. Krupp time-fuze set to explode at 1,094 yards. Burst in air over front target and about 50 feet above ground. Krupp time-fuze set to explode at 1,039 yards. Burst in air 75 yards in front of front target and about 50 feet above ground. Krupp time-fuze set to explode at 1,039 yards. Burst in air over front target and about 40 feet above ground. The shrapnel used in rounds 874, 876, 877, and 878 had brass caps; the caps in rounds 874 and 877 being screwed to the body of the shrapnel and the caps in rounds 876 and 878 being fastened to shrapnel by screw-pins. The shrapnel in round 875 had cast-iron cap which was screwed to the body of the shrapnel. All the shrapnel contained a bursting charge of 1¾ ounces musket powder, and 110 lead balls—32 to the pound—the weight of both bursting charge and bullets being included in the weights given.
Time to striking point.			
4¼	....	....	
Time to bursting point.			
3	....	....	
3	....	....	
3	....	....	

Record of firing with 3.2-inch breech-loading rifle No. 1, S. B. F.,

	No. of fire.	Time.		Powder.			Projectile.			Elevation.		Recoil.
		Month.	Day.	Kind.	Weight.		Kind.	Weight.				
		1884.			*Lbs.*	*Oz.*		*Lbs.*	*Oz.*	°	′	*Feet.*
Barometer, 29.893; thermometer, 62.8; humidity, 68.	1	March.	12	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3	0	Hotchkiss shrapnel.	13	8	2	00	12.00
	2	March.	12		3	0		13	8	1	50	6.75
	3	March.	12		3	0		13	8	1	50	6.75
	4	March	12		3	0		13	8	1	50	6.75
	5	March.	12		3	0		13	8	1	00	6.75
	6	March	12		3	0		13	0	2	00	6.75

at Sandy Hook, N. J., on March 12, 1884.

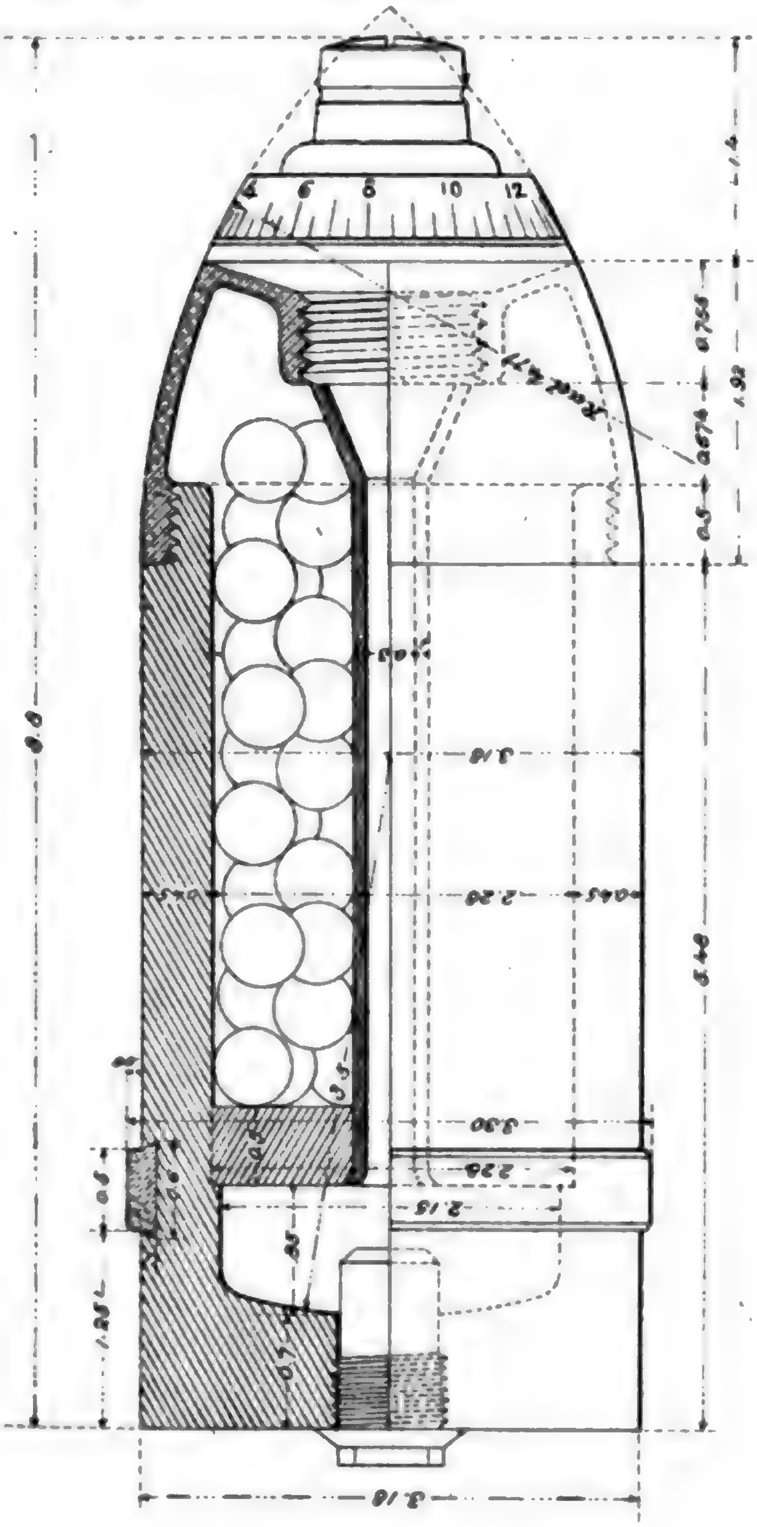
Wind, strength and direction.	Time to bursting point.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
	Seconds.		
From right and front 48°, 38 miles an hour.	¾	Fired at 3 targets in column; 1st 1,100 yards, 2d 1,150 yards, and 3d 1,200 yards from gun. 1st and 2d target 6′ × 39′, 3d target 6′ × 52′, made of 1″ spruce boards.	Krupp time-fuze set to explode at 1,039 yards. Burst in the air 10′ in front of target, and 30′ above ground.
	Lost		Krupp time-fuze set to explode at 1,039 yards. Burst on striking 50′ in rear of front target.
	2¾		Krupp time-fuze set to explode at 984 yards. Burst in the air 30′ in front of target, and 30′ above ground.
From right and front 48°, 22 miles an hour.	3		Krupp time-fuze set to explode at 984 yards. Burst on striking 21 yards in front of target.
	3		Krupp time-fuze set to explode at 984 yards. Struck 20 yards short of target and probably burst.
	Time to striking point.		
	3		Krupp time-fuze set to explode at 984 yards. Went over 1st and 2d targets. Exploded when near mile targets.

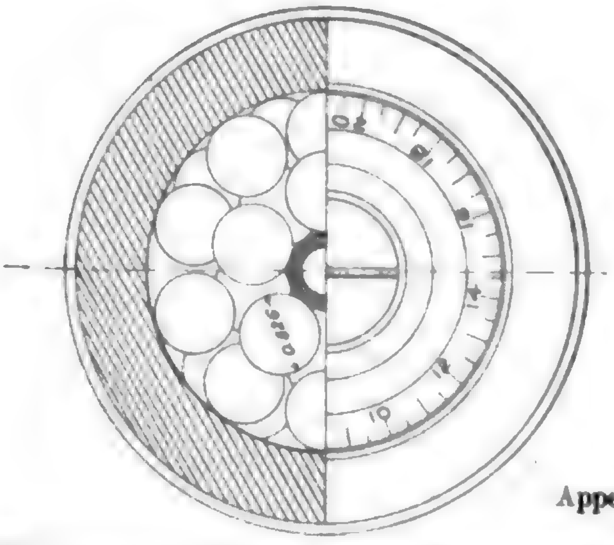
The shrapnel used in rounds 1, 2, 3, 4, and 5 had cast-iron caps screwed to the body of the shrapnel, and contained a bursting charge of 1¾ ozs. musket powder and 110 lead balls 32 to the pound. The weight of the balls and bursting charge being included in the weights given.

The shrapnel used in round 6 had cast-iron cap screwed to the body of the shrapnel, and contained a bursting charge of 1¾ ozs. of musket powder and 108 lead balls 32 to the pound. The weight of bursting charge and balls being included in the weight given.

From rounds 2 to 6, inclusive, wheels locked to trail by ropes.

SHRAPNEL FOR 3.20 INCH B. L. RIFLE





Appendix 16—1884.

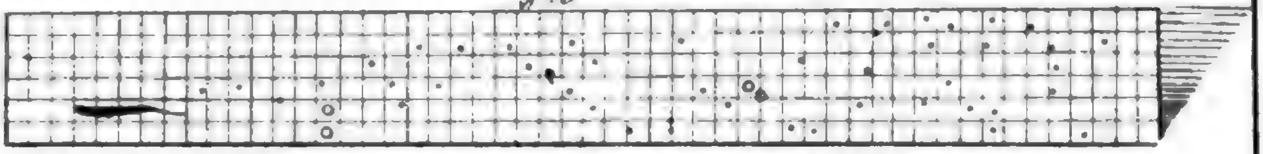
PLATE II.

Target Record of 3.20 B.L. Rifle No 774 + 1

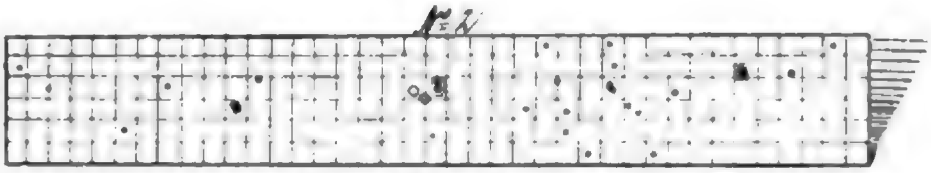
At Sandy Hook N.J.
March 5th & 12th 1884

Target No 1. 700 yds from Gun
Target No 2. 1000 yds from Gun
Target No 3. 1200 yds from Gun

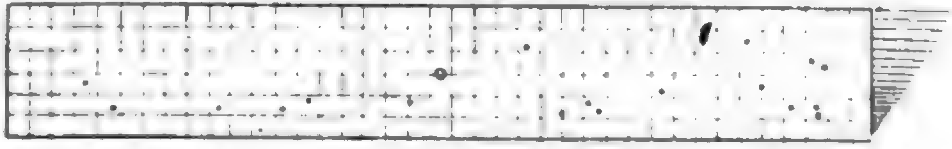
No 3



No 2



No 1



Perforation by bullet ●
Indentation by bullet ●
Perforation by shell [illegible] ○
[illegible] ■
[illegible] ■

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 69

Appendix 16—1884

APPENDIX 17.

TRIAL OF 10-INCH RIFLED MORTARS NOS. 1 AND 2, BY THE ORDNANCE BOARD.

(5 plates.)

By direction of the Chief of Ordnance, in a letter dated July 19, 1883, a test was made of two rifled mortars formed from two 10-inch smoothbore Rodman guns by cutting them off at planes 30 inches from their muzzles and rifling them.

The mortars differed in their rifling, and were numbered 1 and 2. Mortar No. 1 contained thirty lands and thirty grooves 0.075 inches deep of right-handed twist, increasing from one turn in one hundred calibers at the breech to one turn in thirty-five calibers at 1 inch from the muzzle. Mortar No. 2 had forty lands and forty grooves 0.04 inches deep of right-handed twist, increasing from one turn in forty-five calibers at the breech to one turn in twenty-five calibers at 1 inch from the muzzle. In both mortars the length of chamber was 7.5 inches, the length of bore was 82.5 inches, and the length of the rifled part of the bore was 72.5 inches. To overcome their very considerable preponderance a counterpoise ring of lead was cast about the muzzle. For this purpose two wrought-iron rings were placed about the chase, one at the muzzle, the other at a distance of 15 inches from the first, both rings being fastened with set screws. A casing of sheet-iron was then fastened to the periphery of the rings by screws, and an opening in the top of the casing was left, through which was poured a quantity of molten lead sufficient to overcome the preponderance.

The carriage used for these mortars was made by bolting to the interior of the cheeks of a 15-inch carriage radial struts which at their upper extremities bore trunnion beds. Cap squares were also attached to the carriage.

The projectiles were thirty-six ordinary Butler 10-inch shell, provided with three different kinds of sabots, denominated sabots A, B, and C. Sabot A was of the Butler form, differing from those heretofore furnished for the 10-inch shell in that the lip was thirty-one thousandths of an inch thinner, while the groove was deeper. Sabot B was of brass, having a lip 0.25 inch thick at the base and a depth of 0.85 inch, with 30 ribs on the exterior which fitted the grooves in mortar No. 1. Sabot C was made of brass also, and was similar to the Dard sabot described in Construction Notes No. 8, and illustrated in Fig. 15 of that note, but differed from the one therein described by lacking the two grooves on the exterior cylindrical surface. The composition of the alloy was the same for all these sabots.

The programme of trial which the Board was directed to carry out and the expected ranges, velocities, and pressures are shown by the following tabular statement. Projectiles with sabots A and B were to be fired from mortar No. 1; those with sabot C from mortar No. 2 only.

TABLE 1.

Charge.	Density of loading.	Elevation.	Probable range.	Number of rounds.		
				Sabot A.	Sabot B.	Sabot C.
Pounds.	*Cub. in.*	° ′	*Yards.*			
30	38	6 15	2,000 to 2,300	3	3	3
30	38	28 36	6,500	3	3	3
30	38	45	7,000 to 7,500	2	2	2
15	76	60	Not given.	2	2	2
Total number to be fired				10	10	10
Total number supplied				14	10	12
Number remaining to determine initial velocity				4	......	2

For 30-pound charges, velocity required about 980 feet; pressure, about 29,000 pounds.

For 15-pound charges, velocity required from 650 to 700 feet. Pressure in no case to exceed 30,000 pounds.

Distance of base of projectiles from bottom of bore about 17 3 inches.

As the above table shows, ten projectiles of each kind were to be fired, and from the number supplied there were four with sabot A, none with sabot B, and two with sabot C, which could be utilized in determining initial velocity when firing into the butt, and this velocity could also be determined for the three shots in each series fired under 6° 15′. The pressure could be determined for each round.

The trial of mortar No. 1 was commenced August 1, 1883, by firing one round with a sabot A projectile and a charge of 30 pounds of E. V. M. powder, having a specific gravity of 1.750 and a granulation of 72. The air space was 38 cubic inches to a pound of powder, the distance between the base of the projectile and the bottom of the bore being fixed by a stick, 1 inch square, inserted in the cartridge bag. The instrumental velocity at 112 feet from the muzzle was but 858 feet, and as the crusher gauge gave no indication of pressure a second round was fired, in which the conditions of loading were the same, while the distance between the wire targets was so diminished that the instrumental velocity might be determined at 87.5 feet from the muzzle, as it was deemed possible that the recording instruments had been interfered with by the shock of discharge reaching them before they had been actuated by the projectile. The velocity in this second round was 799 feet, which was less than that desired, and as the crusher gauge again failed to indicate any pressure the Rodman gauge was substituted for it.

In the third round fired with a sabot A projectile and the same charge as before, a pound of powder was caused to occupy a space of 36 cubic inches, but the velocity, 828 feet at 87.5 feet from the muzzle, and the pressure, 9,000 pounds per square inch, were so low that, in the fourth round, the air space was reduced to 30 cubic inches per pound of powder. The velocity, 903 feet, and pressure, 14,500 pounds, being still too low, it was concluded that the projectile should be placed in contact with the charge during the subsequent firing. At the fifth round, with the sabot A projectile in contact with its charge, the instrumental velocity at 87.5 feet was 931 feet, and the pressure was

17,500 pounds. This velocity approximated to that laid down in the programme and was considered satisfactory.

The firing under 6° 15′ of three rounds with the sabot A projectile then began, and gave a mean range of 1,994 yards, with a mean lateral deviation of a little over 7 yards, the errors corresponding very nearly to the differences in instrumental velocity, while the projectiles all gave a fair flight.

Three rounds were then fired under the same angle with the sabot B projectile and the same charge of powder. The ranges were lower and the deviations were not quite so regular as with the sabot A projectile. Of the flights one was fair while two were slightly irregular. It was supposed that the diminution of range and the irregularities of flight might have been due to the fact that the sabot B projectiles, which, as stated before, were ribbed, could not rest in contact with the charge, being stopped on reaching the bottom of the grooves, whereas the sabot A projectiles could pass down the bore beyond the groves until they rested upon the cartridge bag. To take up the space between the bottom of the sabot B projectile and the charge 3 pounds of powder were added in the subsequent rounds, making the total charge fired with these shells last mentioned 33 pounds.

Firing under 28° 36′ with the sabot A projectile gave a mean pressure of 22,700 pounds, a mean range of 6,786 yards, and a mean deviation of 45 yards. The mean errors in range and deviation were, respectively, 74 yards and 12.6 yards. As the range of one projectile was lost, four were fired, of which three gave a good and one gave a fair flight.

Three sabot B projectiles were then fired under the same angle with 33 pounds of powder, giving a mean pressure of 18,700 pounds, a mean range of 6,588 yards, and a mean deviation of 59 yards, while the mean errors in range and deviation were 40 yards and 15 yards, respectively. Of the flights two were fair and one was good.

Firing under 45° with the sabot A projectile gave a mean pressure of 20,275 pounds, a mean range of 7,474 yards and a mean deviation of 260.5 yards, while the mean errors were 68.5 yards and 1.5 yards. One projectile gave a slightly irregular, the other a good flight. The sabot B projectile gave a mean range of 7,151 yards and a mean deviation of 287.5 yards, with mean errors in range and deviation of 375 yards and 9.5 yards. One flight was good and one was fair.

Firing under 60° was to be carried on with 15 pounds of powder only, and as a lot of sabots furnished for the Butler 10-inch projectiles some time ago were on hand the projectiles recovered after previous firing were furnished with these old sabots and fired into the butt to determine velocities and pressures. At first the projectile was placed at the same distance from the bottom of the bore as in the preceding rounds, with 30 pounds of powder, but when fired with 15 pounds of sphero hexagonal powder with a density of 1.728 and granulation of 123, it gave such a low velocity and pressure that it was considered impracticable to use any air space with such a charge of this powder. It was then decided to reduce the thickness of the lip of the sabot A to 0.125 inch, make the cannelure in the base 1.25 inch instead of 0.85 inch, and fire a shot with E. V. M. powder, placing the projectile in the same position as when the 30-pound charge was used, and recover the projectile, for which latter purpose it was fired into the butt. Having been recovered, there were no signs that the sabot had taken the grooves, whereupon the projectile was placed directly in contact with the charge and again fired and recovered, with a like result. It was concluded from this that it was impracticable to fire these projectiles with 15-pound charges of such molded powders as we have at present in our service, as their densities, averaging over 1.7, are too great to give the necessary expansion to this sabot.

Two rounds were then fired with the sabot B projectile under the same elevation with one-half the charge used before; that is, with 16.5 pounds of E. V. M. powder, the ribs of the sabot being at the bottom of the grooves. The first shot moved irregularly over a part of its path while the second tumbled. The conclusion is that, with our powders at least, 15 pounds is too small a charge to give regular flights with either the Butler or ribbed projectile in mortar No. 1.

The trial of mortar No. 2 commenced August 14, 1883, with the firing of a 30-pound charge of E. V. M. powder and a projectile furnished with sabot C, which was aimed at the butt in order that velocity and pressure might be determined. The instrumental velocity at 87.5 feet from the muzzle was 958 feet, which being satisfactory, two rounds more were fired with the same charge, but both projectiles "tumbled." One round was then fired with the ordinary Butler sabot and gave a good flight. As the principal object of this firing was to test the action of the sabot C projectile, and as it failed to give any suitable results the firing was discontinued till further orders.

SUMMARY.

In mortar No. 1 the sabot A projectile, with 30-pound charges, gave eight fair flights and one which was slightly irregular.

The sabot B projectile gave one fair and two slightly irregular flights with 30-pound charges, and in the five rounds with 33-pound charges the flights were all fair.

No favorable results were obtained with either of the projectiles when charges less than 30 pounds were fired.

The errors in range and deviation were about the same with the sabot A and with the sabot B projectiles.

It may be concluded that with such molded powders as are now on hand No. 1 mortar with the sabot A projectile gives good results with charges of 30 pounds, and the sabot B projectile with charges of 33 pounds, but the latter is more difficult to load than the former.

In mortar No. 2 the modified Dard sabot was unsatisfactory.

In conclusion, the Board would recommend that a supply of powder having the same granulation as the E. V. type, viz, 72, and a density of nearly but not less than 1.6 be obtained and tried with these mortars. The granulation is made the same to facilitate procuring as small a supply as practicable. Five barrels would be enough for the present. From the experiments thus far completed the Board is unable to form any definite opinion as to the relative merits of the two kinds of rifling.

GEO. W. McKEE,
Major of Ordnance, Senior Member present.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 10-inch rifled mortar, No. 1 (converted from a 10-inch

	Number of fire.	Time.	Powder.			Projectile.		Elevation.	Pressure per square inch of bore.	Instrumental velocity, taken 112 feet from muzzle.	Recoil.
			Kind.	Weight.		Kind.	Weight.				
		1883.		Lbs	Oz.		Lbs	° ′	Lbs.	Feet.	Feet.
A. M.—Barometer, 30.021; thermometer, 78; humidity, 54; wind, 6 miles an hour.	1	Aug. 1	Du Pont's hexagonal, E. V. M. Density, 1.750; granulation, 72.	30	....	Shell, sabot A (new).	351	−1	Crusher gauge used.	858	5.15
	2	Aug. 1		30	....		351	−1		799 Taken 87.5 feet from muzzle.	5.23
P. M.—Barometer, 29.962; thermometer, 85; humidity, 48; wind, 6 miles an hour.	3	Aug. 1		30	....		352	−1	9,000 Rodman pressure-gauge used.	828	5.27
	4	Aug. 1		30	....		352	−1	14,500	903	5.06
	5	Aug. 1		30	....		352	−1	17,500	931	4.83
A. M.—Barometer, 29.852; thermometer, 74; humidity, 85; wind, 16 miles an hour.	6	Aug. 2		30	....		352	6 15	20,000	948	4.08
	7	Aug. 2		30	....		352	6 15	18,500	938	4.01
	8	Aug. 2		30	....		352	6 15	19,200	937	4.08
A. M.—Barometer, 29.975; thermometer, 72; humidity, 53; wind, 16 miles an hour.	9	Aug. 3		30	....	Shell, sabot B (new).	351	6 15	11,000	857	6.17
	10	Aug. 3		30	....		351	6 15	11,600	867	4.62
	11	Aug. 3		30	....		351	6 15	12,250	862	4.41
P. M.—Barometer, 29.978; thermometer, 78; humidity, 68; wind, 21 miles an hour.	12	Aug. 3		30	....	Shell, sabot A. New.	351	28 36	22,700	......	3.50
	13	Aug. 3		30	....		351	28 36	21,000	......	3.33
	14	Aug. 3		30	....		351	28 36	24,500	......	3.08
	15	Aug. 3		30	....	Shell, sabot A. Resaboted.	351	28 36	23,600	......	3.15
	16	Aug. 3		33	....	Shell, sabot B (new).	352	28 36	17,600	......	2.85
	17	Aug. 3		33	....		352	28 36	19,100	......	3.25
	18	Aug. 3		33	....		352	28 36	18,500	......	3.15
A. M.—Barometer, 30.192; thermometer, 71; humidity, 71; wind, 4 miles an hour.	19	Aug. 8	Du Pont's sphero-hexagonal, I B. A. Density, 1.728; granulation, 123.	15	....	Shell, sabot A (resaboted).	350	1 10	4,250	746	1.65
	20	Aug. 8		15	....		350	1	4,800	508	2.69

Rodman smooth-bore), at Sandy Hook, N. J., from August 1 to August 9, 1883.

Counter recoil.	Wind, strength and direction.	Ranges.	Deflection to right.	Time of flight.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.			
Feet.		*Yds.*	*Yds.*	*Secs.*				
.08	From front and left, 17°; 6 miles an hour.	.....	.....	.....	Fired into sand butt.	Density of loading 38 cubic inches to the pound, a stick 17".4 long being inserted in cartridge to maintain projectile in proper position.		To overcome preponderance a band was attached to the muzzle consisting of 1,845 pounds of lead inclosed in an iron casing, the whole weighing 2,295 pounds.
.06		.....	.....	.....				
....		.....	.....	.....		Density of loading 36 cubic inches to the pound; length of stick, 16".3. Rodman substituted for crusher gauge in this and subsequent rounds; density of loading 30 cubic inches to the pound; length of stick, 14".		To adapt the 15 inch carriage selected to this mortar false trunnion beds were added, 2½" thick, which were supported on the inside by an additional brace, 3½" square, bolted to the cheeks on the inside, along the line of the middle strut.
...		.....	.....	.....				
....		.....	.....	.....				
.02	From front and right, 2°; 16 miles an hour.	2,013	7	....	Fired down beach.	Rounds 5 to 18, inclusive, no stick used and no air space.	Flight fair.	
.03		1,981	8	.....			Flight fair.	Muzzle band started; all case-screws in rear end of band broken and band started forward.
.03		1,990	7⅝	.....			Flight fair.	Muzzle band started forward about 4" on top and 5" below. After this round band removed, repaired, and replaced more securely.
.02	Wind 16 miles an hour; from rear and right, 88°.	1,697	7	.....			Flight fair.	
.03		1,707	2	....			Slightly irregular flight.	
.06		1,697	4	.....			Slightly irregular flight.	
.06	Wind 21 miles an hour; from rear and right, 39°.	6,890	64	28	Fired over water for ranges.		Flight good.	
.05		Lost.	.....	Lost.			Flight fair.	
.05		6,675	37	27¾			Flight good.	
.05		6,793	34	27¼			Flight good.	
.07		6,580	36	26¾			Flight fair.	
.05		6,648	64	26¾			Flight good.	Left cheek of carriage showing signs of buckling.
.06		6,536	77	27			Flight fair.	Both cheeks of carriage, the right slightly, show signs of buckling.
.01	Wind 4 miles an hour; from rear and right, 80°.	.....	.....	.....	Fired into sand butt.	Density of loading double that used in rounds 5 to 18, inclusive.		Before firing round No. 19 cheeks of carriage repaired, as follows: Brace, 3½" wide, moved forward and replaced by 3½" square brace, and third brace added in rear, 3½" square, for 16", and below 1" by 3½". Two lugs on each side inserted between cheeks, bolted to them and screwed to trunnion bed-plates. 1½" assembling bolt added just in front of upper part of front transom. ¾" bolts for 2d and 3d cheek struts replaced by 1" bolts.
.02		.....	....	.....				

Record of firing with 10-*inch rifled mortar, No.* 1 (*converted from a*

	Number of fire.	Time.	Powder. Kind.	Powder. Weight.		Projectile. Kind.	Projectile. Weight.	Elevation.	Pressure per square inch of bore.		Instrumental velocity, taken 112 feet from muzzle.		Recoil.
		1883.		*Lbs*	*Oz.*		*Lbs*	° ′	*Lbs.*		*Feet.*		*Feet.*
P. M.—Barometer, 30.151; thermometer; 79; humidity, 38; wind, 7 miles an hour.	21	Aug. 8	Dupont's hexagonal, E. V. M. Density, 1.750; granulation, 72.	30	....	Shell, sabot A (new).	353	45	21, 800	Rodman pressure-gauge used.	......	Taken 87.5 feet from muzzle.	5. 10
	22	Aug. 8		30	....		350	45	18, 750		......		2. 92
	23	Aug. 8		33	...	Shell, sabot B (new).	353	45	19, 100		......		2. 67
	24	Aug. 8		33	...		353	45	17, 000		......		3. 04
A. M.—Barometer, 30.135; thermometer, 76; humidity, 60; wind, 4 miles an hour.	25	Aug. 9		15	...	Shell, sabot A (resaboted).	352	−3°	500		362		0. 94
	26	Aug. 9		15	...		350	−1°	500		404		2. 35
	27	Aug. 9		16	8	Shell, sabot B (new).	352	60	1, 000		......		0. 50
P. M.—Barometer, 30.122; thermometer, 77; humidity, 64; wind, 7 miles an hour.	28	Aug. 9		16	8		353	60	4, 500		......		0. 52

10-inch ***Rodman smooth-bore***), *at Sandy Hook, N. J., &c.*—Continued.

Counter recoil.	Wind, strength and direction.	Ranges.	Deflection to right.	Time of flight.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.		*Yds.*	*Yds.*	*Secs.*		
.03	From front and right, 30°; 7 miles an hour.	7,543	262	39¾	Fired over water for ranges.	Front transom bolt upper carriage broke. Slightly irregular flight.
.04		7,406	259	39½		Flight good.
.04		7,526	297	38½		Rounds 21 and 22; density of loading the same as in rounds 5 to 18. Flight good.
.03		6,776	278	37¾		Density of loading the same as rounds 5 to 18; that is, no air space, and as shot with B sabot could not be inserted so far within the bore 3 pounds of powder had to be added to charge. Flight fair.
.02	From rear and left, 42°; 4 miles an hour.	.....	.....	.....	Fired into sand butt.	Density of loading double that used in rounds 21 and 22. No air space. Exterior lip of sabot thinned to ⅛"; depth of cannelure in base increased to 1".25.
.03		.....	.....	.....		
.....	From rear and left, 31°; 4 miles an hour.	1,588	107	.....	Fired down beach	Flight fair.
.....	From left to right, 90°; 7 miles an hour.	1,579	96	23½		Density of loading double that used in rounds 23 and 24. Shot tumbled.

Record of firing with 10-inch rifled mortar

[Converted from a 10-inch

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure, pounds per square inch of bore.	Instrumental velocity 87.5 feet from muzzle.	Recoil.	Wind strength and direction.
			Kind.	Weight.	Kind.	Weight.					
		1883.		*Lbs.*		*Lbs.*	° ′	*Lbs.*	*Feet.*	*Feet.*	
								Rodman gauge used.			
A. M.—Barometer, 30.144; thermometer, 71; humidity, 62; wind 12 miles an hour.	1	Aug. 14	Du Pont's hexagonal E. V. M. Density, 1.750; granulation, 72.	30	......	349	—¾°	23,000	958	7.25	From rear and right 17°; 12 miles an hour.
	2	Aug. 14		30	Sabot C (new).	350	6 15	18,400	943	5.33	
	3	Aug. 14		30	......	350	6 15	12,300	892	4.60	
	4	Aug. 14		30	Sabot A (new).	350	6 15	12,700	911	5.33	......

No. 2, at Sandy Hook, N. J., on August 14, 1884.

Rodman smooth-bore.]

Counter recoil.	Ranges.	Deflection to right.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.		
Feet.	*Yards.*	*Yds.*			
0.06	....	...	Fired into butt ...	Shot recovered. Sabot stripped, and marks on it indicated slipping in grooves.	Same band to overcome preponderance as used with mortar No. 1, but with 35 pounds less of lead used with this mortar, making its weight 2,260 pounds. Muzzle band moved slightly forward.
0.03	1,853	17	Fired down beach.	Density of loading same as rounds 5 to 18 in mortar No. 1—that is, no air space.	Flight very irregular.
0.03	1,779	19			Flight very irregular.
0.04	1,843	15			Flight good.

Star-gauging of 10-inch rifled mortar No. 1.

Inches from muzzle.	August 1, 1883, original diameter of bore.	August 3, 1883, diameter after 11 rounds.	August 9, 1883, diameter after 24 rounds.	August 11, 1883, diameter after 28 rounds.	Inches from muzzle.	August 1, 1883, original diameter of bore.	August 3, 1883, diameter after 11 rounds.	August 9, 1883, diameter after 24 rounds.	August 11, 1883, diameter after 28 rounds.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*
72	10.009	10.011	10.010	10.011	36	10.010	10.013	10.013	10.014
71	10.009	10.011	10.010	10.012	35	10.010	10.013	10.013	10.014
70	10.009	10.011	10.011	10.011	34	10.010	10.013	10.013	10.014
69	10.009	10.011	10.011	10.011	33	10.010	10.013	10.013	10.014
68	10.010	10.011	10.011	10.011	32	10.010	10.013	10.013	10.014
67	10.010	10.011	10.011	10.011	31	10.010	10.013	10.013	10.014
66	10.009	10.011	10.011	10.011	30	10.010	10.013	10.013	10.014
65	10.009	10.012	10.011	10.012	29	10.010	10.013	10.013	10.014
64	10.009	10.012	10.011	10.012	28	10.010	10.013	10.013	10.014
63	10.009	10.012	10.012	10.012	27	10.010	10.013	10.013	10.014
62	10.009	10.012	10.012	10.012	26	10.010	10.013	10.013	10.014
61	10.010	10.012	10.012	10.012	25	10.010	10.013	10.013	10.014
60	10.010	10.012	10.012	10.012	24	10.010	10.012	10.013	10.015
59	10.010	10.012	10.012	10.013	23	10.010	10.012	10.014	10.014
58	10.010	10.012	10.012	10.013	22	10.010	10.013	10.014	10.014
57	10.010	10.012	10.012	10.013	21	10.010	10.013	10.014	10.014
56	10.010	10.012	10.012	10.012	20	10.010	10.013	10.014	10.015
55	10.010	10.012	10.013	10.013	19	10.011	10.013	10.015	10.015
54	10.011	10.012	10.012	10.013	18	10.011	10.014	10.015	10.015
53	10.010	10.012	10.012	10.013	17	10.011	10.014	10.015	10.015
52	10.010	10.012	10.012	10.013	16	10.011	10.014	10.015	10.015
51	10.010	10.012	10.013	10.013	15	10.011	10.014	10.015	10.015
50	10.010	10.012	10.014	10.014	14	10.012	10.014	10.015	10.015
49	10.010	10.012	10.013	10.013	13	10.012	10.014	10.014	10.015
48	10.010	10.012	10.013	10.014	12	10.011	10.014	10.015	10.015
47	10.010	10.012	10.013	10.014	11	10.012	10.015	10.015	10.015
46	10.010	10.012	10.013	10.014	10	10.011	10.015	10.016	10.016
45	10.010	10.013	10.013	10.014	9	10.011	10.015	10.015	10.016
44	10.010	10.013	10.012	10.014	8	10.012	10.015	10.015	10.016
43	10.010	10.012	10.012	10.014	7	10.012	10.014	10.015	10.016
42	10.010	10.012	10.013	10.014	6	10.012	10.015	10.016	10.018
41	10.010	10.012	10.013	10.013	5	10.012	10.015	10.016	10.017
40	10.010	10.012	10.013	10.013	4	10.012	10.015	10.016	10.017
39	19.010	10.012	10.013	10.013	3	10.012	10.016	10.016	10.017
38	10.010	10.012	10.013	10.013	2	10.013	10.017	10.016	10.017
37	10.010	10.012	10.013	10.013	1	10.015	10.017	10.017	10.018

CONTINUATION OF TRIALS REPORTED AUGUST 18, 1883.

This trial was ordered in a letter from the Chief of Ordnance dated December 22, 1883.

The principal dimensions of the mortars are as follows:

	Mortar No. 1.	Mortar No. 2.
	Inches.	*Inches.*
Length of bore, total	90	90
Length of rifling	72.5	72.5
Diameter of bore	10	10
Number of lands	30	40
Number of grooves	30	40
Width of lands	0.350	0.015
Width of grooves	0.690	0.6354
Depth of grooves	0.075	0.040

TWIST: Mortar No. 1, from 1 turn in 100 calibers at breech to 1 in 35 calibers 1 inch from muzzle. Mortar No. 2, from 1 turn in 45 calibers at breech to 1 in 25 calibers 1 inch from muzzle.

During the trials reported in August, 1883, three kinds of projectiles, denominated sabot A (Butler). sabot B (ribbed to fit grooves), sabot C (Dard), were fired with full and reduced charges of E. V. M. powder, which has a specific gravity of 1.750 and 72 grains to the pound. None of these projectiles gave satisfactory results when 15-pound charges were used; it was therefore recommended that powder having a specific gravity of 1.6 should be obtained for further experiment in firing reduced charges. The sabot C projectile did not give satisfactory results with 30-pound charges of E. V. M. powder during the experiments referred to, but when in September three rounds (Nos. 5, 6, and 7 of the accompanying record for mortar No. 2) were fired with the same charges and the same powder, the flight of the projectiles was good. The sabot A and sabot B projectiles gave good results when fired from mortar No. 1 with 30 and 33 pound charges, respectively. None of these were at that time fired from mortar No. 2.

The instructions of December 22, 1883, directed a continuation of the trials, "the object being to ascertain which kind of sabot and which of the two varieties of rifling gives greatest accuracy of fire both with full and reduced charges."

The projectiles furnished were of three kinds: (1) Sabot A (Butler), (2) sabot C (Dard), (3) Arrick.

The sabots of the first were of the ordinary Butler pattern, with the groove made deeper and the lip made thinner.

The sabots of the second had the same cross-section as that of the Dard projectile, illustrated in Construction Notes No. 8.

The sabots of the third were of the ordinary Arrick pattern, made a little lighter.

The following kinds of powder were on hand, viz: E. V. M., granulation, 72; specific gravity, 1.75. E. V. K., granulation, 72; specific gravity, 1.75. The latter was, when first received, stronger than the former.

The following powders were sent for use in these trials: K. I., granulation, 72; specific gravity, 1.65. K. K., granulation, 72; specific gravity, 1.60.

To assimilate the firing from these pieces to firing with chambered mortars, it was necessary that the base of the projectile should remain at a fixed distance from the bottom of the bore, and for this purpose there was placed in the axis of the cartridge a pine stick, 1 square inch in cross-section, and of such length that the density of loading with a charge of 30 pounds was 33.4 cubic inches to the pound.

The trial of mortar No. 2 commenced December 28, 1883. A sabot A (Butler) projectile was fired with 15 pounds K. I. powder (1.65 specific gravity), and gave evidence of irregular flight as it entered the butt sidewise. A 15-pound charge of K. K. powder (1.60 specific gravity) with a similar projectile gave the same result.

The third round (round No. 10 of the accompanying record) consisted of 15 pounds of K. K. powder and an Arrick projectile. This shot, recovered after firing, was found to have taken the grooves well, as furthermore it had moved with 676 feet velocity, and as the pressure was but 11,250 pounds per square inch, it was concluded to fire a series of rounds with a similar charge and projectile under 60° elevation.

Four rounds (11, 12. 13, and 14 of the record) were fired; all of the flights were good. The first of this series of four was fired down the beach, but the point of fall could not be ascertained. The remainder were fired over the sea, and the plane tables were used to locate the point struck.

Powder.		Projectile.		Ranges.	Error in range.	Deviation right.	Error in deviation.	Pressure per square inch.
Kind.	Weight.	Kind.	Weight.					
	Pounds.		*Pounds.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Pounds.*
K. K	15	Arrick..........	348	3, 322	+ 44	348	−15	11, 750
K. K	15	....do	347	3, 426	+148	372	+ 9	10, 750
K K	15	....do	348	3, 087	− 191	369	+ 6	10, 500
Mean ..	15	....	348	3, 278	128	363	10	11, 000

Dispersion, in range, 339 yards; in direction, 24 yards.

In the above table the dispersion in range is the difference between the maximum and minimum ranges, and the dispersion in direction is the difference between the maximum and minimum deviations.

Three rounds were then fired under 60° elevation with the sabot C (Dard) projectile and 15-pound charges of K. K. powder.

Powder.		Projectile.		Ranges.	Error in range.	Deviation right.	Error in deviation.	Pressure per square inch.
Kind.	Weight.	Kind.	Weight.					
	Pounds.		*Pounds.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Pounds.*
K. K	15	Sabot C (Dard.).	349	3, 265	− 117	327	+ 50	11, 000
K. K ..	15	... do	349	3, 454	+ 72	235	− 42	12, 000
K. K	15	... do	349	3, 427	+ 45	209	− 8	11, 500
Mean..	15	....	349	3, 382	78	277	33	11, 500

Dispersion, in range, 189 yards; in direction, 92 yards.

The first flight was slightly irregular, the second fair, the third good.

A sabot A (Butler) shot was then fired with the same charge and elevation, but the flight was very irregular.

In Ordnance Board Report No. 11, 1883, it was concluded that it was impracticable to fire sabot A projectiles with 15-pound charges of molded powders having a specific gravity greater than 1.7, and from the firing last referred to it seems that no better results are obtained with powder of 1.6 specific gravity.

The next point to be determined was whether any of the sabots which were suitable for use with 15-pound charges would give good results greater charges.

Three rounds (Nos. 19, 20, and 21 of the record) were fired with 30-pound charges of E. V. M. powder and Arrick projectiles; one good flight and two bad ones were obtained.

E. V. K. powder, a little stronger than E. V. M., gave no better results. It was then determined to use the stronger powders, K. I. and K. K., and 25 pound charges of the latter seemed suitable for use with the Arrick projectile. As the projectile occupied the same position in the bore during all of the firing, the air space, or density of loading, was with 25-pound charges 40.1 cubic inches per pound.

Two rounds (27 and 28 of the record) under an angle of 28° 36′ gave one fair and one good flight with a mean pressure of 26,500 pounds per square inch. One range only (5,035 yards with a deviation of 349 yards to the right) was obtained, and as it was necessary to retain some of these projectiles to fire them from mortar No. 1, this ended the firing of Arrick projectiles from mortar No. 2.

Three sabot C (Dard) projectiles were then fired under 28° 36′ with 30 pounds of E. V. K. powder with the following results:

Powder.		Projectile.		Ranges.	Error in range.	Deviation right.	Error in deviation.	Pressure per square inch.
Kind.	Weight.	Kind.	Weight.					
	Pounds.		*Pounds.*	*Yards*	*Yards.*	*Yards.*	*Yards.*	*Pounds.*
E. V. K	30	Sabot C (Dard)	349	5, 752	— 55	172	— 15	20, 000
E. V. K	30	... do	349	5, 588	+109	218	+ 31	19, 500
E. V. K	30	W. P. F., sabot C (Dard)	350	5, 752	— 55	172	— 15	19, 250
Mean	30	....	349	5, 697	73	187	20	19, 583

Dispersion: In range, 164 yards; in direction, 46 yards.

The density of loading was 33.4 cubic inches to the pound of powder, and the pressure was lower than that given in the two preceding charges with a density of 40.1 cubic inches to the pound, but the powder was of 1.750 specific gravity, while that used in the preceding charges had a specific gravity of 1.60. The flights of the projectiles were all fair.

From the results obtained when firing mortar No. 2 it was concluded: That the present form of sabot on sabot A (Butler) projectiles was not suited for firing from this mortar with reduced charges; that good results could be obtained when firing reduced charges of K. K. powder (1.6 specific gravity) with sabot C (Dard) projectiles or with Arrick projectiles; that good results could not be obtained in firing reduced charges of powder having 72 grains to the pound, and a density exceeding 1.6 with any of the projectiles thus far used.

From the firing with charges exceeding 15 pounds in mortar No. 2 it was concluded: That the Arrick projectile does not give good results when fired with 30 pounds of E. V. powder (specific gravity 1.75); that this projectile gave indications that with 25 pounds of K. K. powder (specific gravity 1.60) fair results may be obtained, but that further experiment will be required to determine this point; that the sabot C (Dard) projectile gives good results with 30-pound charges of the E. V. powders.

The trial of mortar No. 1 commenced January 5, 1884, by firing three rounds with the Arrick projectiles and 15 pounds of K. K. powder under 60° elevation (rounds 29, 30, and 31 of accompanying record of mortar No. 1).

Powder.		Projectile.		Ranges.	Error in range.	Deviation right.	Error in deviation.	Pressure per square inch.
Kind.	Weight.	Kind.	Weight.					
	Pounds.		*Pounds.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Pounds.*
K. K.........	15	Arrick........	346	3, 656	....	279	....	12, 250
K. K.........	15	....do	346	3, 428	....	342	....	12, 500
Mean	15	....	346	3, 542	114	311	31	12, 375

The point of fall of the third shot was not located. The flights were all good.

With a 30-pound charge of E. V. K. powder and an Arrick projectile, fired under 28° 36′, the shot tumbled, although the sabot had been reamed out to make it more sensitive.

Two rounds were then fired with 25 pounds K. K. powder (specific gravity 1.60) and the Arrick projectile under 28° 36′ (rounds 33 and 34 of record).

Powder.		Projectile.		Ranges.	Error in range.	Deviation right.	Error in deviation.	Pressure per square inch.
Kind.	Weight.	Kind.	Weight.					
	Pounds		*Pounds.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Pounds.*
K. K.	25	Arrick	346	5, 277		313		28, 500
K. K.	25	....do	346½	6, 067		334		29, 500
Mean	25		346	5, 672	395	324	10	29, 000

The flights were good.

It was concluded from the firing of mortar No. 1: That with 15-pound charges of powder having 1.6 specific gravity the Arrick projectile gives good results, and that with 25-pound charges of the same powder the same remarks apply.

The number of rounds fired was not sufficient to determine the relative merits of the two kinds of rifling.

It is recommended that the experiment be continued to settle this point, and for this purpose that 25 each of the Arrick and Dard projectiles be supplied. It is suggested that the base of the sabot of the Arrick projectile be made thinner than in the projectiles heretofore furnished to make the expanding disc more sensitive.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 10-inch rifled mortar No. 2, at Sandy Hook,

[Converted from a 10-inch

	Number of fire.	Time.	Powder.		Projectile.		Elevation.		Pressure per square inch of bore.	Instrumental velocity, 111 feet from muzzle.
			Kind.	Weight.	Kind.	Weight.				
		1880.		Lbs.		Lbs.	°	′	Lbs.	Feet.
Barometer, 30.006; thermometer, 71; humidity, 84.	5	Sept. 21	Du Pont's hexagonal, E. V. M. Density 1.750; granulation, 72.	30	Sabot C. (new)	352	6	15	17, 500	......
	6	Sept. 21	....do	30	....do	349	6	15	18, 000	......
	7	Sept. 21	....do	30	....do	348	20		17, 200	......
									Rodman.	
Barometer, 29.892; thermometer, 28; humidity, 43.	8	Dec. 28	Du Pont's K. I. Density, 1.650; granulation, 72.	15	Butler resaboted; sabot A.	353	—½		6, 750	629
	9	Dec. 28	Du Pont's K. K. Density, 1.600; granulation, 72.	15	....do	352	—½		9, 500	645
	10	Dec. 28	....do	15	Arrick (new) .	349	—½		11, 250	676
Barometer, 30.293; thermometer, 30; humidity, 47.	11	Dec. 29	....do	15	....do	349	60		9. 000	......
	12	Dec. 29	....do	15	....do	348	60		11, 750	......
	13	Dec. 29	....do	15	... do	347	60		10, 750	......
	14	Dec. 29	....do	15	....do	348	60		10, 500	......
	15	Dec. 29	....do	15	Sabot C. (Dard.)	349	60		11, 000	......
	16	Dec. 29	....do	15	....do	349	60		12, 000	......
	17	Dec. 29	....do	15	....do	349	60		11, 500	......
	18	Dec. 29	....do	15	Butler resaboted; sabot A.	350	60		12, 500	......
Barometer, 29.872; thermometer, 26.1; humidity, 64.	19	Jan. 3	Du Pont's hexagonal, E. V. M. Density, 1.750; granulation, 72.	30	Arrick (new) .	346	28	36	16, 000	......
	20	Jan. 3	....do	30	....do	346	28	36	10, 250	......
	21	Jan. 3	....do	30	....do	346	28	36	10, 000	......
	22	Jan. 3	Du Pont's E. V. K. Density, 1.750; granulation, 72.	30	Butler sabot A	353	—½		18, 500	927
	23	Jan. 3	....do	30	Arrick (new) .	349	28	36	20, 500	......

N. J., from September 21, 1883, *to January* 4, 1884.

Rodman smooth-bore gun.]

Recoil.	Wind, strength and direction.	Counter recoil.	Time of flight.	Range.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.		*Feet.*	″	*Yards.*	*Yards.*	
4.58	From front and left, 86°; 4 miles an hour.	......	......	1,947	8 right..	Fired down beach. Flight good. 14 inches from base of shot to bottom of bore. Shot seated against cartridge, leaving no air space.
3.83	....do	......	......	1,909	10 right..	
2.71	From front and left, 68°; 4 miles an hour.	......	......	......	....	Fired out to sea. Flight good.
2.75	From rear and right, 88°; 42 miles an hour.	......	......	......	....	Fired into sand butt. Keyholed.
2.75	....do	......	......	......	....	Do.
2.33	....do	......	......	......	....	Fired into sand butt. Shot recovered and found to have taken rifling well.
0.46	From rear and right, 80°; 18 miles an hour.	.01	......	......	....	Fired down beach. Good flight.
0.46	....do	.46	37¾	3,322	348 right..	Fired out to sea. Good flight.
0.61	....do	.01	37¼	3,426	372 right..	Do.
0.58	....do	.46	36	3,087	369 right.	Do.
0.35	....do	.35	36½	3,265	327 right	Fired out to sea. Slightly irregular.
0.62	....do	.01	35¼	3,454	235 right..	Fired out to sea. Fair flight.
0.48	....do	.42	36¾	3,427	269 right..	Fired out to sea. Good flight.
0.48	....do	.42	35¼	3,342	156 right..	Fired out to sea. Very irregular flight.
						Rounds 8 to 18, inclusive: Density of loading, 66.8 cubic inches to the pound.
3.25	From front and right, 55°; 36 miles an hour.	2.75	26¾	5,585	124 right..	Fired out to sea. Good flight. Two of the screws fastening muzzle-band became loose.
						Before firing round No. 20 friction recoil-check put on carriage.
1.58	....do	0	22¾	3,256	1 left	Fired out to sea. Very irregular. Tumbled.
1.50	....do	0	23¼	4,496	95 right..	Fired out to sea. Very irregular. Muzzle-band partially broken up by shock of firing.
3.48	....do	0	0	......	....	Fired into sand butt. Keyholed. Entire muzzle-band broke up and fell off.
2.42	....do	0	23¼	4,201	92 right...	Fired out to sea. Very irregular. No band used on muzzle; gun held in position by blocking. Preponderance overcome by coiling chain around muzzle during remainder of firing.

Record of firing with 10-*inch rifled mortar No.* 2, *at Sandy Hook*,

	Number of fire.	Time.	Powder.		Projectile.		Elevation.		Pressure, per square inch of bore (Rodman).	Instrumental velocity, 111 feet from muzzle.
			Kind.	Weight.	Kind.	Weight.				
		1883.		*Lbs.*		*Lbs.*	°	′	*Lbs.*	*Feet.*
Barometer, 30.205; thermometer, 19; humidity, 53.	24	Jan. 4	Du Pont's K. K. Density, 1.600; granulation, 72.	20	Butler sabot A	352	—¼		16, 500	806
	25	Jan. 4	...do	25	....do	347	—¼		27, 750	917
	26	Jan. 4	Du Pont's K. L Density, 1.650; granulation, 72.	25	....do	354	—¼		26, 500	909
	27	Jan. 4	Du Pont's K. K. Density, 1.600; granulation, 72.	25	Arrick........	347	28	36	27, 000	......
	28	Jan. 4	....do	25	....do	347	28	36	26, 000	......
	29	Jan. 4	Du Pont's E. V. K. Density, 1.750; granulation, 72.	30	Sabot C. (Dard.)	349	28	36	20, 000	......
	30	Jan. 4	....do	30	....do	349	28	36	19, 500	......
	31	Jan. 4	....do	30	W. P. F.; sabot C. (Dard.)	350	28	36	19, 250	......

NOTE BY ORDNANCE OFFICE.—With the exception of rounds 5, 6, and 7 a stick 15½ inches in length was used in the cartridges.

N. J., from September 21, 1883, *to January* 4, 1884—Continued.

Recoil.	Wind: strength and direction.	Counter recoil.	Time of flight.	Range.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.		*Feet.*	"	*Yards.*	*Yards.*	
2.17	From rear and right, 80°; 28 miles an hour.	0.08	0	....	....	Fired into sand butt. Broke plate supporting right hand guide hook. Cracked elevating prop.
2.50	...do	0	0	....	....	Fired into sand butt. Broke elevating prop. Same replaced by a new one. Shot recovered and found to have taken grooves well.
2.50	do	0	0	....	....	Fired into sand butt. Broke elevating prop; replaced by new one.
1.12	....do	0.08	26¾	5,035	349 right..	Fired out to sea. Fair flight.
1.12	.. do	0.08	26½	Lost..	....	Fired out to sea. Good flight.
1.67	...do	0.08	26⅓	5,752	172 right..	Fired out to sea. Fair flight.
1.2	....do	0.08	26⅓	5,588	218 right..	Do.
1.04	....do	0.08	26½	5,752	172 right..	Do.

Rounds 19, 20, 21, 22, 23, 29, 30, 31: Density of loading, 33.4 cubic inches per pound of powder.
Round 24: Density of loading, 50.1 cubic inches per pound of powder.
Rounds 25, 26, 27, 28: Density of loading, 40.1 cubic inches per pound of powder.

Record of firing with 10-inch rifled mortar No.

[Converted from a 10-inch

	Number of fire.	Time.	Powder.		Projectile.			Elevation.		Pressure per square inch of bore.
			Kind.	Weight.	Kind.	Weight.				
		1884.		*Lbs.*		*Lbs.*	*ozs.*	°	′	*Lbs.*
Barometer, 30.168; thermometer, 12; humidity, 80.	29	Jan. 5	Du Pont's K. K. Density, 1.600; granulation, 72.	15	Arrick (new) ..	346	0	60		12,250
	30	Jan. 5	......do	15	....do	346	0	60		12,500
	31	Jan. 5	.......do	15	Arrick (old lot)	346	4	60		10,250
	32	Jan. 5	DuPont's E. V. K. Density, 1.750; granulation, 72.	30	Arrick (new) ...	347	0	28	36	15,500
	33	Jan. 5	Du Pont's K. K. Density, 1.600; granulation, 72.	25	....do	346	0	28	36	28,500
	34	Jan. 5	......do	25	Arrick (old lot).	346	4	28	36	29,500

Rounds 29, 30, 31. Density of loading, 66.8 cubic inches per pound of powder.
Round 32. Density of loading, 33.4 cubic inches per pound of powder.
Round 33, 34. Density of loading, 40.1 cubic inches per pound of powder.

1, *at Sandy Hook, N. J., on January* 5, 1884.

Rodman smooth-bore gun.]

Recoil.	Wind, strength, and direction.	Counter recoil.	Time of flight.	Ranges.	Deflection.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.		*Feet.*	"	*Yds.*	*Yds.*		
0.3	From rear and left 10°, 16 miles an hour.	0.35	36¾	3,656	279 right	Fired out to sea.	Good flight. Chain used on muzzle as counterpoise.
1.04	....do	0.02	37¼	3,428	342 right		Good flight.
0.3	....do	0.25	Lost	Lost	....		Good flight. Chassis rail right hand side cracked.
1.46	....do	0.04	22¼	3,380	267 right		Tumbled. (Base of sabot reamed out.)
1.58	.. do	0.08	27	5,277	318 right		Good flight. Mortar jumped out of bearings and turned eccentric ring.
1.50	....do	0.08	27	6,067	334 right		Good flight. Mortar jumped out of bearings and turned eccentric ring. (Base of sabot reamed out.)

NOTE BY ORDNANCE OFFICE.—In all the above rounds a stick 15¼ inches in length was used in the cartridges.

CONTINUATION OF TRIALS REPORTED AUGUST 18, 1883, AND JANUARY 28, 1884.

The experiments initiated in August, 1883, were continued during December, 1883, and January, 1884, and resumed in March, 1884.

The preceding trials had indicated that fair results could be obtained with the Arrick and Dard projectiles, but it was necessary to modify them slightly and to fire a greater number to ascertain which of the two kinds of rifling was the better.

The projectiles used in the last series of firing were of two kinds, viz, the Arrick, with a comparatively thin sabot, and the Dard, with a sabot lighter than any previously used. In addition to the Arrick sabots affixed to the projectiles were five made still lighter, to be used in case of necessity.

The powders were of three kinds: E. V. K., density, 1.75, granulation, 72; K. K., density, 1.65, granulation, 72; K. I., density, 1.60, granulation, 72.

The trial of mortar No. 1 was commenced by firing an Arrick projectile with its sabol in place as furnished by the West Point Foundry Association, followed by one to which a lighter sabol was appended. These rounds (Nos. 35 and 36 of the firing record) showed that there was no appreciable difference in the results obtained, and in all of the subsequent firing with Arrick projectiles the heavier sabot was used.

The Arrick and Dard projectiles were then fired under 28° 36′, with thirty-pound charges of E. V. K. powder, five rounds of each being fired alternately. The results are given in the following tables:

TABLE No. 1.—*Mortar No. 1.*

[Arrick projectile: weight, 344 pounds. Angle of elevation, 28° 36′. Initial velocity, 999 feet.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation, left.	Error.	Time of flight.	Pressure on square inch.
			Yards.	*Yards.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
37	1	Good	7,317	+ 88	70	5.2	30	22,000
39	2	do	7,232	+ 3	46	18.8	29.75	25,000
41	3	Fair	7,205	— 24	79	14.2	28.75	24,000
43	4	Good	7,189	— 40	50	14.8	29	23,500
45	5	Fair	7,202	— 27	79	14.2	28.5	23,250
		Mean	7,229	36.4	64.8	13.4	29.2	23,550

Charge: 30 pounds E. V. K.; granulation, 72; density, 1.75.
Dispersion: In direction, 33 yards; in range, 128 yards.

TABLE No. 2.—*Mortar No. 1.*

[Dard projectile: weight, 334 pounds. Angle of elevation, 28° 36′.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation, left.	Error.	Time of flight.	Pressure on square inch.
			Yards.	*Yards.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
38	1	Slightly irregular.	Lost.	....	....	....	30.25	22,250
40	2	do	6,916	— 80	59	— 9.25	28.75	26,000
42	3	Fair	7,046	+ 50	64	— 4.25	29	27,000
44	4	do	6,972	— 24	74	+ 5.75	29	30,500
46	5	Slightly irregular.	7,049	+ 53	76	+ 7.75	29.25	25,500
		Mean	6,996	51.7	68.25	6.75	29.25	26,250

Charge: 30 pounds E. V. K.; granulation, 72; density, 1.75.
Dispersion: in direction, 17 yards; in range, 133 yards.

Five rounds of each kind of projectiles were fired under 60° with fifteen-pound charges of K. K. powder and an air space of 66.8 cubic inches to the pound. The results are tabulated below:

TABLE No. 3.—*Mortar No.* 1.

[Arrick projectile: weight, 346 pounds. Angle of fire, 60°.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation, rg	Error.	Time of flight.	Pressure on square inch.
			Yards.	*Yards.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
47	1	Good	3,666	+ 95	167	+ 13	37.25	10,750
49	2	......do	3,538	— 33	148	— 6	36	8,250
51	3	......do	3,533	— 38	148	— 6	36.25	8,500
53	4	......do	3,510	— 61	152	— 2	36.50	9,250
55	5	......do	3,610	+ 39	156	+ 2	36.75	9,250
		Mean	3,571	55.2	154	5.8	36.55	9,200

Charge: 15 pounds K. K.; granulation, 72; density, 1.650.
Dispersion; in direction, 19; in range, 156.

TABLE No. 4.—*Mortar No.* 1.

[Dard projectile: weight, 336 pounds. Angle of fire, 60°.]

Number of Record.	Number of series.	Nature of flight.	Range.	Error.	Deviation.		Error.	Time of flight.	Pressure on square inch.
					Left.	Right.			
			Yards.	*Yards.*	*Yds.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
48	1	Good	3,546	+ 101.4	......	158	+ 72.6	35.75	8,750
50	2	Fair	3,547	+ 102.4	......	26	— 59.4	35.5	10,500
52	3	Very irregular	2,947	— 497.6	3	......	88.4	33	11,000
54	4	Good	3,580	+ 135.4	......	130	+ 44.6	36.75	11,500
56	5	......do	3,603	— 158.4	......	116	+ 30.6	36.5	12,000
		Mean	3,444.6	199.0	......	85.4	59.1	35.50	10,750

Charge: 15 pounds K. K.; granulation, 72; density, 1.650.
Dispersion: in direction, 161 yards; in range, 656 yards.

The trial of mortar No. 2 was carried on in the same way as that for mortar No. 1 and the tables given below show the results.

TABLE No. 5.—*Mortar No.* 2.

[Arrick projectile: weight, 345 pounds. Angle of fire, 28° 36′. Initial velocity, 979 feet.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation.		Error.	Time of flight.	Pressure on square inch.
					Left.	Right.			
			Yards.	*Yards.*	*Yds.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
34	1	Good	6,820	+17	35	......	36.4	29.5	47,000
36	2	.. do	6,795	— 8	11	......	12.4	28.75	23,500
38	3	...do	6,776	−27	......	34	32.6	29	52,500
40	4	.. do	6,776	−27	......	34	32.6	28.75	27,750
42	5	....do	6,847	+44	15	......	16.4	29	26,000
		Mean ..	6,803	24.6	......	1.4	26.1	29.00	*25,750

* Mean of three results as pressures in Nos. 1 and 3 are considered erroneous

Charge: 30 pounds E. V. K.; granulation, 72; density, 1.75.
Dispersion: In direction, 69 yards; in range, 71 yards.

TABLE No. 6.—*Mortar No. 2.*

[Dard projectile: weight, 334 pounds. Angle of fire, 28° 36′. Initial velocity, 970 feet.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation, left.	Error.	Time of flight.	Pressure on square inch.
			Yards.	*Yards.*	*Yds*	*Yards.*	*Secs.*	*Pounds.*
35	1	Fair	6, 481	− 38. 8	31	−34. 6	29. 25	27, 250
37	2	Irregular	6, 528	+ 8. 2	49	−16. 6	28. 75	25, 500
39	3	Slightly irregular	6, 633	+113. 2	78	+12. 4	28. 50	26, 000
41	4	....do	6, 466	− 53. 8	56	− 9. 6	28. 25	25, 000
43	5	Very irregular..	6, 491	− 28. 8	114	+48. 4	28. 25	26. 500
		Mean......	6, 519. 8	48 56	65. 6	24. 32	28. 6	26, 050

Charge: 30 pounds E. V. K.; granulation, 72; density, 1.750.
Dispersion: In direction, 83 yards; in range, 167 yards.

TABLE No. 7.—*Mortar No. 2.*

[Arrick projectile: weight, 343 pounds. Angle of fire, 60°.]

Number of record.	Number of series.	Nature of flight.	Range.	Error.	Deviation, right.	Error.	Time of flight.	Pressure on square inch.
			Yards.	*ards.*	*Yds.*	*Yards.*	*Secs.*	*Pounds.*
44	1	Good	3, 772	+146. 4	215	−11	38	11, 500
46	2	....do	3, 622	− 3. 6	243	+17	38	10, 000
48	3	....do	3, 529	− 96. 6	221	− 5	37. 25	10, 000
50	4	....do	3, 600	− 25. 6	231	+ 5	37	8, 000
51	5	...do	3, 605	− 20. 6	220	− 6	37. 75	11, 500
		Mean	3, 625. 6	58. 56	226	8. 8	37. 6	10, 200

Charge: 15 pounds K. I.; granulation, 72; density, 1.650.
Dispersion: In direction, 28 yards; in range, 172 yards.

TABLE No. 8.—*Mortar No. 2.*

[Dard projectile: weight, 335 pounds. Angle of fire, 60°.]

No. of record.	No. of series.	Charge.	Nature of flight.	Range.	Deviation.		Time of flight.	Pressure on square inch.
					Left.	Right.		
				Yards.	*Yards.*	*Yards.*	*Secs.*	*Pounds.*
45	1	15 pounds KI; granulation, 72; density, 1.650.	Very irregular.	2, 350	207	....	29. 25	11, 000
47	2		...do	2, 326	....	107	30. 25	11, 500
49	3		...do	2, 286	199	....	32. 00	11, 750
52	4	15 pounds KK; granulation, 72; density, 1.600.	...do	2, 297	377	....	31. 50	10, 500

Not summed as flights; were all very irregular.

The Dard projectiles, fired from mortar No. 2, gave such inferior results that only four of them were found at 60° elevation.

The mean results of the foregoing tables will be found in table No. 9.

TABLE No. 9.—*Summary.*

ARRICK PROJECTILE.

	Angle of fire.		Range.	Error.	Deviation.			Dispersion.		Time of flight.	Pressure on square inch.
					Left.	Right.	Error.	Direction.	Range.		
	°	'	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Yards.*	*Seconds*	*Pounds*
Mortar No. 1.	28	36	7,229	36.4	64.8	....	13.4	93	126	29.2	23,550
Mortar No. 2.	28	36	6,803	24.6	....	1.4	26.1	69	71	29	25,750
Mortar No. 1.	60		3,571	55.2	....	154	5.8	19	156	36.55	9,200
Mortar No. 2.	60		3,626	58.6	....	226	8.8	28	172	37.6	10,200

DARD PROJECTILE.

Mortar No. 1.	28	36	6,996	51.7	68.25	....	6.7	17	133	29.25	26,250
Mortar No. 2.	28	36	6,519	48.6	66	....	24.3	83	167	28.6	26,050
Mortar No. 1.	60		3,445	199	....	85.4	59.1	161	656	35.5	10,750

An examination of the tabulated results shows that the Arrick projectile experimented with gave better results than the Dard, and that, all things considered, mortar No. 1 was superior to mortar No. 2.

The carriage from which these mortars were fired was not sufficiently rigid to obtain great accuracy in range. The platform upon which the carriage was mounted sustained considerable injury during the firing at high angles. It is thought that with a heavy mortar-bed far more accurate results will be obtained.

Firing records and sketches which show the groups of the projectiles are forwarded with this report.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 10-*inch rifled mortar No.* 1 *at*

[Converted from a 10-inch

	Number of fire.	Time.	Powder.		Projectile.					
			Kind.	Weight.	Kind.	Weight.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity, 87.6 feet from muzzle.
		1884.		*Lbs.*		*Lbs.*	*ozs.*	° ′	*Lbs.*	*Feet.*
Barometer, 29.658; thermometer, 52.3; humidity, 63.	35	Mar. 27	Du Pont's E. V. K. Density, 1.750; granulation, 72.	30	Arrick (new). Sabot, 14¾.	347	0	6 15	22, 250	997
	36	Mar. 27	....do	30	Arrick (new). Sabot, 14¼.	346	8	6 15	23, 750	995
Barometer, 29.738; thermometer, 51; humidity, 68.	37	Mar. 28	....do	30	Arrick (new).	344	0	28 36	22, 000	.....
Barometer, 29.660; thermometer, 47; humidity, 69.	38	Mar. 29	....do	30	Dard (new) ...	334	0	28 36	22, 250	.....
	39	Mar. 29	....do	30	Arrick (new) .	344	0	28 36	25, 000	.....
	40	Mar. 29	....do	30	Dard (new) ..	334	0	28 36	26, 000	.....
	41	Mar. 29	....do	30	Arrick (new) .	344	0	28 36	24, 000	.....
Barometer, 29.574; thermometer, 55; humidity, 59.	42	Mar. 29	....do	30	Dard (new) ...	334	0	28 36	27, 000	.....
	43	Mar. 29	....do	30	Arrick (new) .	344	0	28 36	23, 500	...
	44	Mar. 29	....do	30	Dard (new) ...	334	0	28 36	30, 500	.....
	45	Mar. 29	....do	30	Arrick (new) .	344	0	28 36	23, 250	.....
	46	Mar. 29	....do	30	Dard (new) ...	334	0	28 36	25, 500	....
	47	Mar. 29	Du Pont's K. I. Density, 1.650; granulation, 72.	15	Arrick (new) .	346	0	60 00	10, 750	....
	48	Mar. 29	....do	15	Dard (new) ...	337	0	60 00	8, 750	.....
Barometer, 29.810; thermometer, 49; humidity, 59.	49	Apr. 1	....do	15	Arrick (new)	346	0	60 00	8, 250	....
	50	Apr. 1	....do	15	Dard (new) ...	336	0	60 00	10, 500	.....
	51	Apr. 1	....do	15	Arrick (new) .	346	0	00 00	8, 500	....
	52	Apr. 1	....do	15	Dard (new) ...	336	0	60 00	11, 000	....
	53	Apr. 1	....do	15	Arrick (new) .	346	0	60 00	9, 250	.....
	54	Apr. 1	....do	15	Dard (new) ...	336	8	60 00	11, 500	.....
	55	Apr. 1	....do	15	Arrick (new) .	346	0	60 00	9, 250	.....
	56	Apr. 1	....do	15	Dard (new) ...	336	8	60 00	12, 000	....

Rounds 35 to 46 inclusive. Density of loading, 33.4 cubic inches.

Sandy Hook, N. J., from March 27 to April 1, 1884.

Rodman smooth-bore gun.]

Recoil.	Wind strength and direction.	Line of fire.	Time of flight.	Range.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.			"	*Yards.*	*Yards.*	
4. 50	From rear and right 43°, 32 miles an hour.	Fired down beach.	7¼	2, 195	6 left....	Good flight.
3. 33	....do		7¼	2, 204	2 left....	Do.
1. 75	From rear and right 60°, 16 miles an hour.	Fired over water.	30	7, 317	70 left....	Good flight. Gun jumped out of trunnion beds, and angle pieces bolted to carriage so as to increase their height in rear. Mortar lashed to carriage.
1. 67	From rear and left 30°, 18 miles an hour.		30¼	Lost.	....	Slightly irregular flight.
2. 25	....do		29¾	7, 232	46 left....	Good flight.
1. 92	....do		28¾	6, 916	59 left....	Slightly irregular flight.
2. 08	....do		28¾	7, 205	79 left ..	Fair flight.
3. 33	From rear and right 18°, 8 miles an hour.		29	7, 046	64 left....	Do.
2. 83	....do		29	7, 189	50 left....	Good flight.
2. 33	....do		29	6, 972	74 left ...	Fair flight.
2. 50	....do		28½	7, 202	79 left....	Do.
3. 33	....do		29¼	7, 049	76 left....	Slightly irregular flight.
0. 50	....do		37¼	3, 660	167 right ..	Good flight.
0. 67	....do		35¾	3, 456	158 right ..	Do.
0. 29	From rear and right 60°, 14 miles an hour.		36	3, 538	148 right ..	Do.
0. 37	....do		35½	3, 547	26 right ..	Fair flight.
0. 58	....do		36¼	3, 533	148 right ..	Good flight.
0. 67	....do		33	2, 947	3 left....	Very irregular flight.
0. 42	....do		36½	3, 510	152 right ..	Good flight.
0. 50	....do		36¾	3, 580	130 right ..	Do.
0. 50	....do		36¾	3, 610	156 right ..	Do.
0. 33	....do		36¼	3, 603	116 right ..	Do.

Rounds 47 to 56 inclusive. Density of loading, 66.8 cubic inches.

Record of firing with 10-inch rifled mortar No. 2, at

[Converted from a 10-inch

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity, 87.6 feet from muzzle.
			Kind.	Weight.	Kind.	Weight.			
		1884.		*Lbs.*		*Lbs. ozs.*	° ′	*Lbs.*	*Feet.*
Barometer, 29.918; thermometer, 46; humidity, 66.	32	Apr. 8	Du Pont's E. V. K. Density, 1,750; granulation, 72.	30	Arrick (new)	347 0	6 15	20,000	977
	33	Apr. 8	...do	30	Dard (new)	335 8	6 15	25,000	968
	34	Apr. 8	...do	30	Arrick (new)	345 0	28 36	47,000	....
	35	Apr. 8	...do	30	Dard (new)	334 0	28 36	27,250	....
	36	Apr. 8	...do	30	Arrick (new)	345 0	28 36	23,500	....
	37	Apr. 8	...do	30	Dard (new)	334 0	28 36	25,500	....
	38	Apr. 8	...do	30	Arrick (new)	345 0	28 36	52,500	....
	39	Apr. 8	...do	30	Dard (new)	334 0	28 36	26,000	....
	40	Apr. 8	...do	30	Arrick (new)	345 0	28 36	27,750	....
	41	Apr. 8	...do	30	Dard (new)	334 0	28 36	25,000	....
	42	Apr. 8	...do	30	Arrick (new)	345 0	28 36	26,000	....
	43	Apr. 8	...do	30	Dard (new)	334 0	28 36	26,500	....
Barometer, 29.877; thermometer, 45; humidity, 69.	44	Apr. 8	Du Pont's K. I. Density, 1,650; granulation, 72.	15	Arrick (new)	343 0	60 00	11,500	....
	45	Apr. 8	...do	15	Dard (new)	335 0	60 00	11,000	....
	46	Apr. 8	...do	15	Arrick (new)	343 0	60 00	10,000	....
	47	Apr. 8	...do	15	Dard (new)	335 0	60 00	11,500	....
	48	Apr. 8	...do	15	Arrick (new)	343 0	60 00	10,000	....
	49	Apr. 8	...do	15	Dard (new)	335 0	60 00	11,750	....
Barometer, 29.429; thermometer, 41.5; humidity, 83.	50	Apr. 9	...do	15	Arrick (new)	343 0	60 00	8,000	....
	51	Apr. 9	...do	15	...do	343 0	60 00	11,500	...
	52	Apr. 9	Du Pont's K. K. Density, 1,600; granulation, 72.	15	Dard (new)	335 0	60 00	10,500	....

Rounds 32 to 43, inclusive, density of loading, 33.4 cubic inches.
Rounds 44 to 52, inclusive, density of loading, 66.8 cubic inches.

Sandy Hook, N. J., from April 8 to April 9, 1884.

Rodman smooth bore.]

Recoil.	Wind: strength and direction.	Line of fire.	Time of flight.	Range.	Deflection.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet.			"	*Yards.*	*Yards.*	
3.33	From front and left 70°, 14 miles an hour.	Fired down beach.	Lost.	2,015	8 right..	Good flight. Shell contained 1 pound sand.
3.00	....do		Lost.	2,070	13 right..	Very irregular flight. Shell contained 1 pound sand.
1.83	From front and left 70°, 14 miles an hour.	Fired over water.	29½	6,820	35 left....	Good flight.
1.83	..do		29¼	6,481	31 left....	Fair flight.
1.83	From front and right 68°, 14 miles an hour.		28¾	6,795	11 left....	Good flight.
2.00	....do		28¾	6,528	49 left....	Irregular flight.
1.83	... do		29	6,776	34 right..	Good flight.
2.00	....do		28½	6,633	78 left....	Slightly irregular.
1.67	....do		28¾	6,776	34 right..	Good flight. Shell contained 1 pound sand.
2.00	....do		28¼	6,466	56 left....	Slightly irregular.
1.67	... do		29	6,847	15 left....	Good flight. Shell contained 1 pound sand.
1.83	....do		28¼	6,491	114 left....	Very irregular flight. Shell contained 1 pound sand.
0.50	From front and right 20°, 11 miles an hour.		38	3,772	215 right..	Good flight. Before this round supporting strap for muzzle band repaired.
0.50	....do		29½	2,350	207 left....	Very irregular flight.
0.50	....do		38	3,622	243 right..	Good flight.
0.50	....do		30½	2,326	107 right..	Very irregular flight.
0.42	....do		37½	3,529	221 right..	Good flight.
0.42	....do		32	2,286	199 left...	Very irregular flight.
0.58	From front and right 20°, 14 miles an hour.		37	3,600	231 right..	Good flight.
0.83	....do		37¾	3,605	220 right..	Good flight. Shell contained 1 pound sand.
0.75	....do		31½	2,297	377 left....	Very irregular flight.

PLATE II.

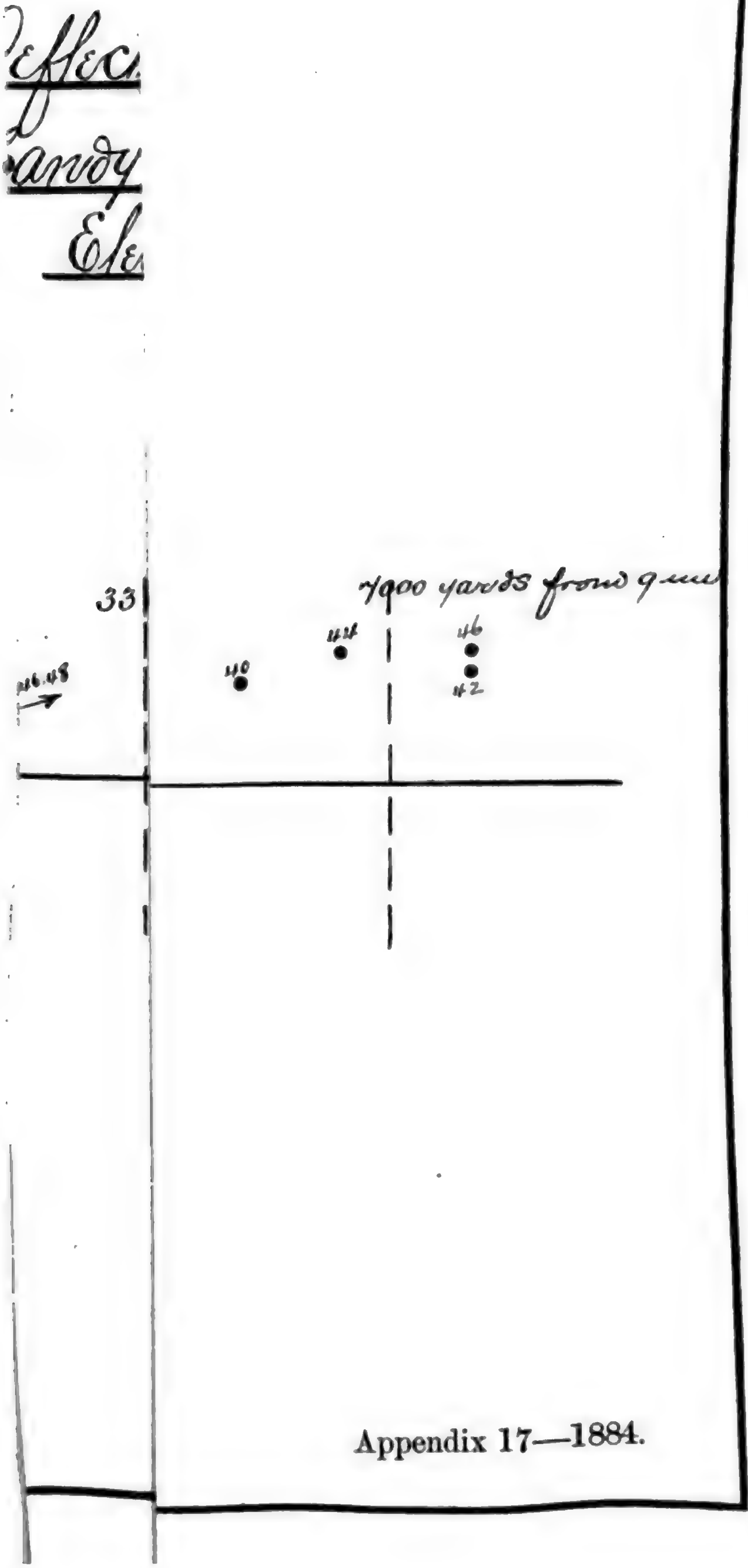


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PLATE III.

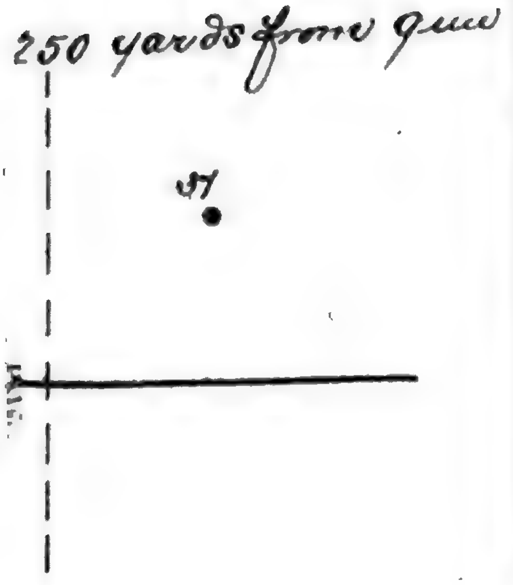

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PLATE IV.

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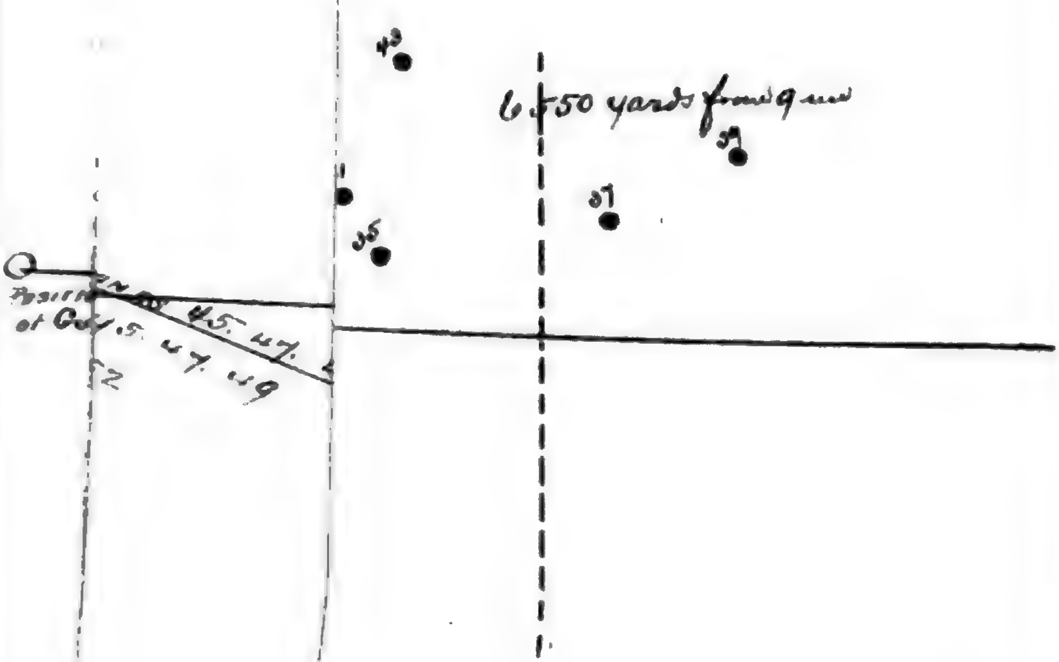
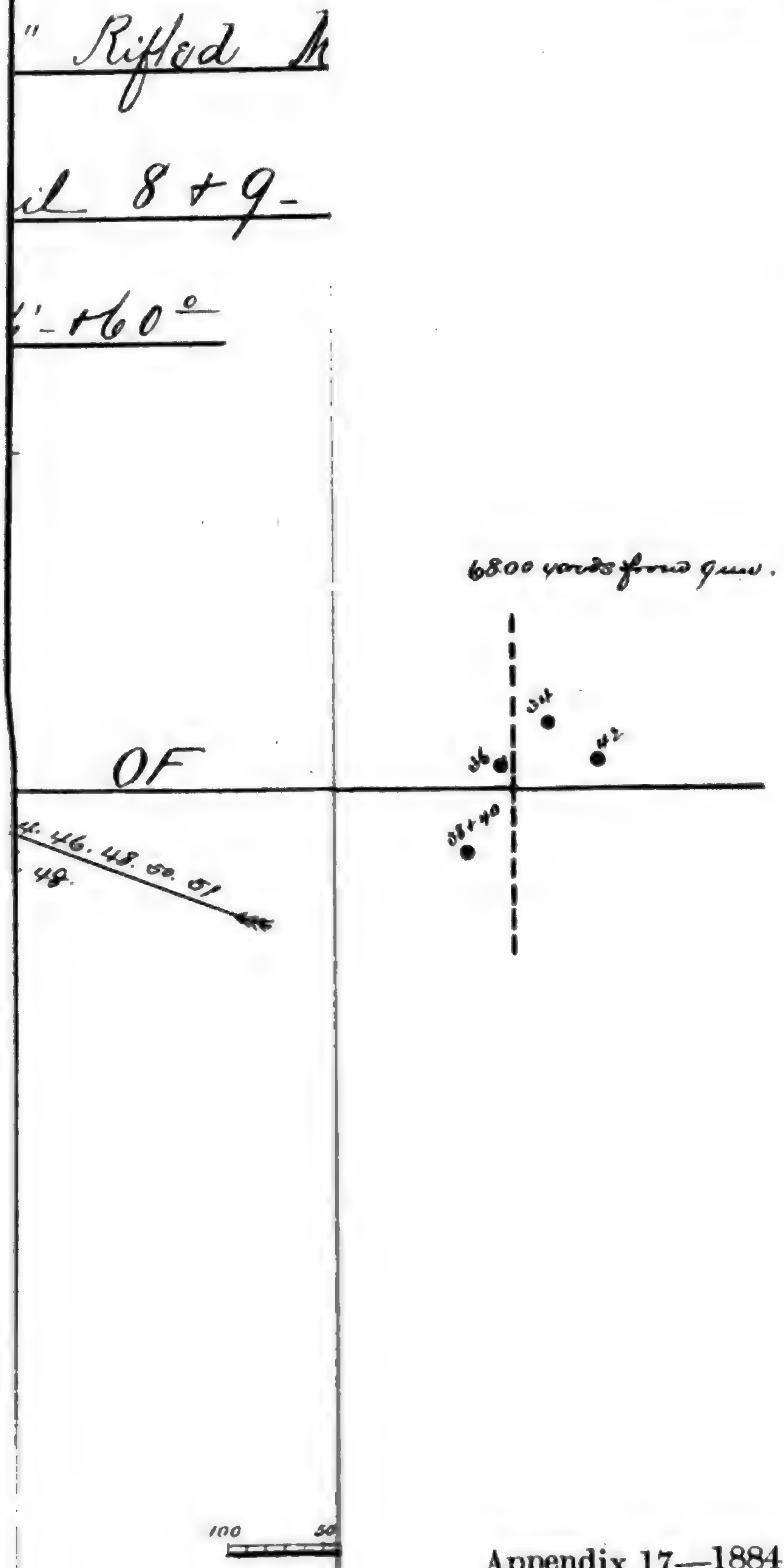
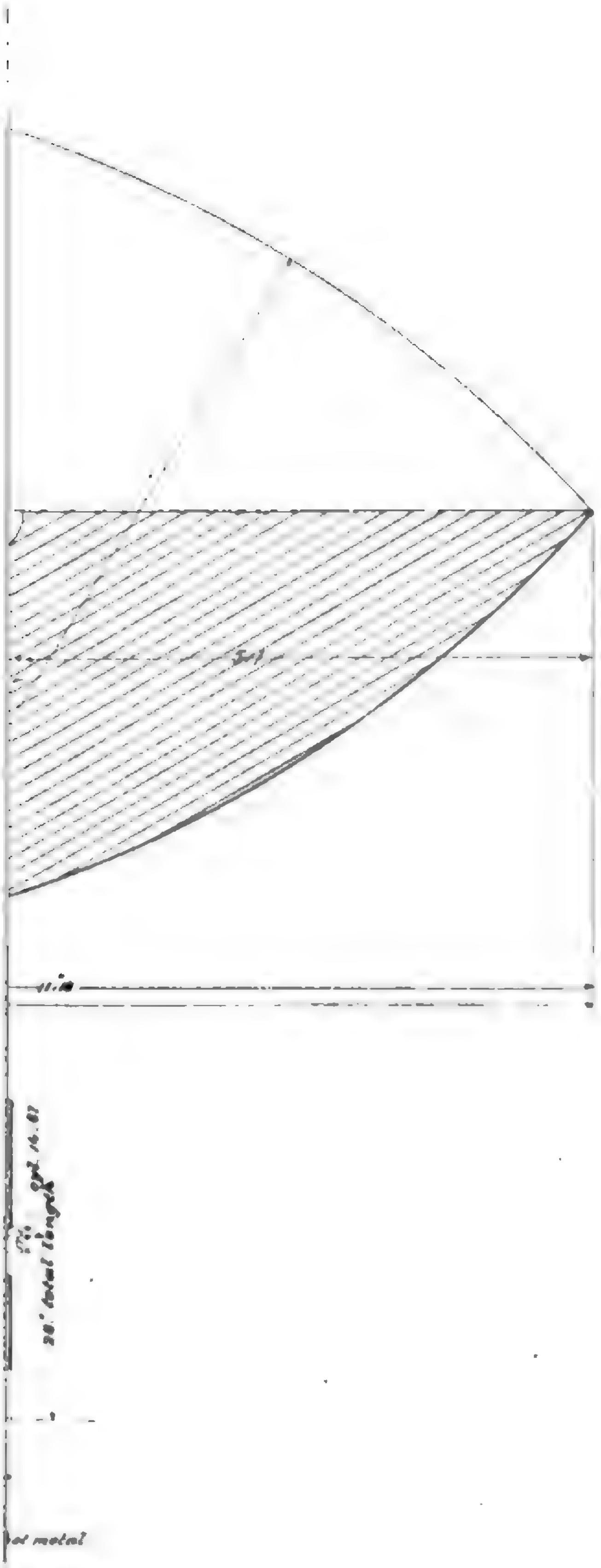


Appendix 17—1884.

PLATE V.



Appendix 17—1884.



Captain of Ordnance,
Principal Assistant

PLATE VII.

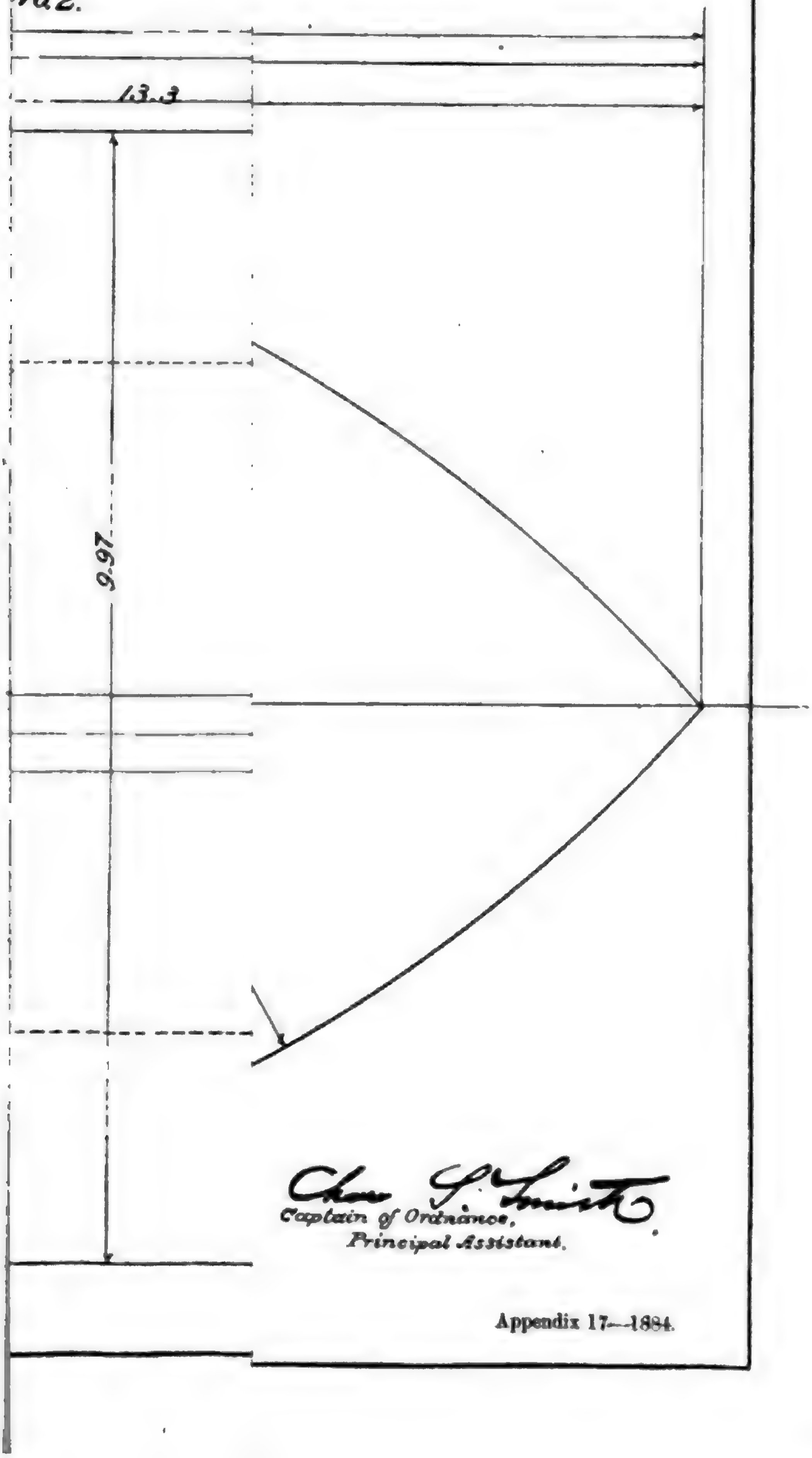
for Experim

OFFICE U.S.A.

Scale

r 350 Lbs.

No. 2.



Chas. S. Smith
Captain of Ordnance,
Principal Assistant.

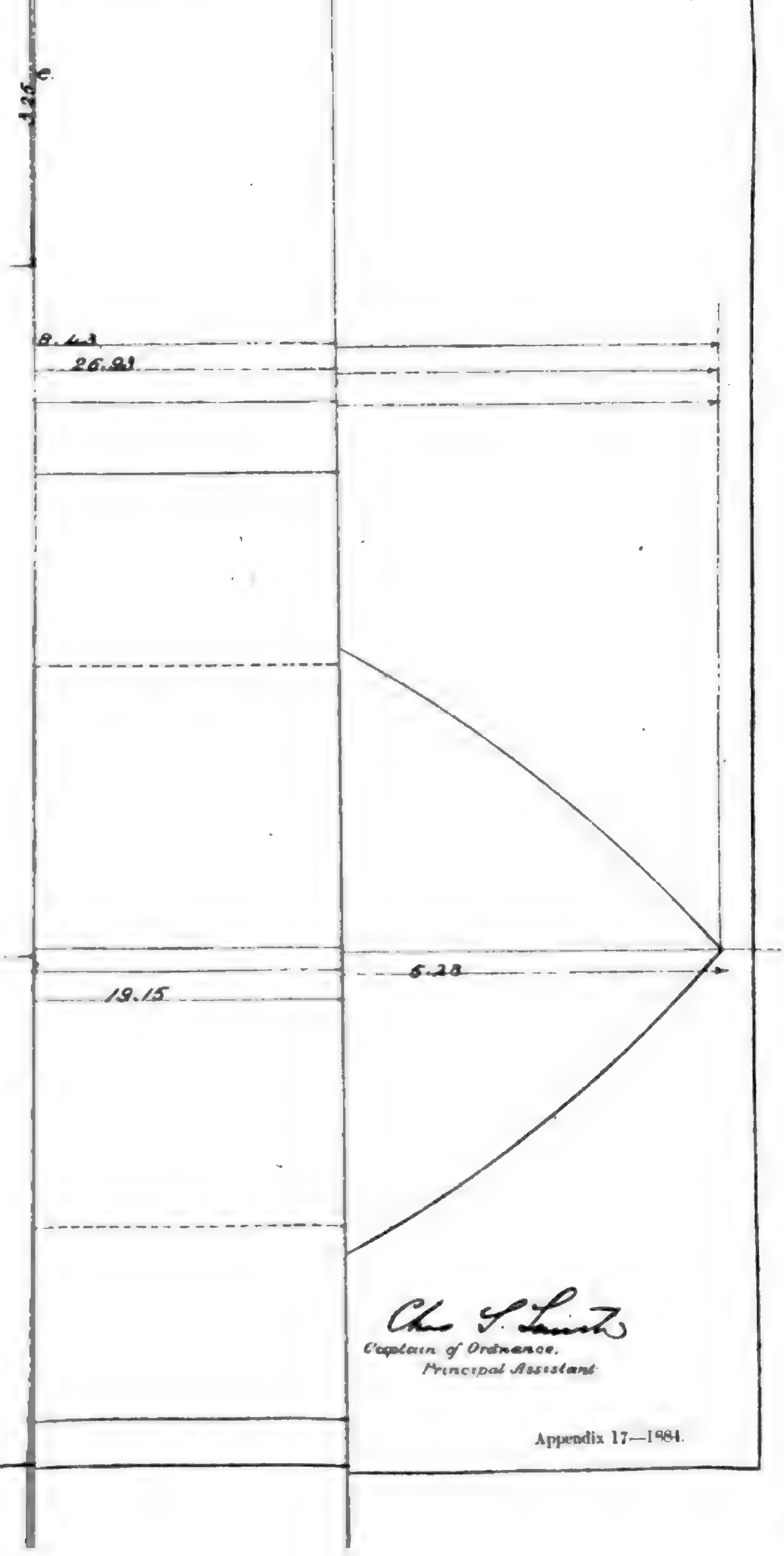
Appendix 17—1884.

PLATE VIII.

r 25 Shell 344 lbs Mar 25-1884

m Report of West Point Foundry Feb 8th 1884

al Mortar.



Chas S. Smith
Captain of Ordnance,
Principal Assistant

Appendix 17—1884.

APPENDIX 18.

TRIAL OF THE IMPROVED GARDNER GUN, CALIBER .45, BY THE ORDNANCE BOARD.

(13 plates.)

In a letter dated May 5, 1884, the Chief of Ordnance directed that should the Messrs. Pratt & Whitney, of Hartford, Conn., present one of their two-barreled machine guns, formerly known as the Gardner gun, the Ordnance Board should have it tried at Sandy Hook and report.

It was necessary to obtain Government ammunition with the 500-grain bullet, as it was stated that the gun now known as the "improved Gardner gun" could use either that kind of ammunition or the cartridges with the 405-grain bullet.

The gun has been fully described and illustrated in the Report of the Chief of Ordnance for 1880, page 387 *et seq.* The nomenclature has been changed and is as follows:

1. Casing body.
2. Casing cover.
3. Hinge pin.
4. Hinge-pin washer.
5. Cascabel.
6. Cascabel screw.
7. Rear sight.
8. Rear-sight guide.
9. Rear-sight spring.
10. Rear-sight-guide screws (2).
11. Rear-sight pinion.
12. Rear-sight-pinion head.
13. Rear-sight-pinion head-pin.
14. Front sight.
15. Barrels (2).
16. Front barrel plate.
17. Front barrel plate-pin.
18. Rear barrel plate.
19. Rear barrel plate-pin.
20. Lock cam.
21. Lock-cam journal boxes (2).
22. Journal box pin.
23. Hand crank.
24. Hand-crank pin.
25. Hand-crank handle.
26. Crank-handle spindle.
27. Spindle nut (hex.).
28. Spindle-nut washer.
29. Spindle nut (round).
30. Lock frames (2).
31. Lock-frame heads (2).
32. Lock-frame trucks (2).
33. Lock-frame truck pins (2).
34. Extractors (2).
35. Extractor pins (2).
36. Sears (2).
37. Sear pins (2).
38. Sear springs (2).
39. Sear-spring pins (2).
40. Mainsprings (2).
41. Firing pins (2).
42. Firing-pin racks (2).
43. Cocking levers (2).
44. Cocking-lever pins (2).
45. Cocking-lever stay pins.
46. Cocking cam.
47. Cocking-cam screw.
48. Cocking-cam pins (2).
49. Lock guide.
50. Lock-guide pin.
51. Shell starters (2).
52. Shell-starter pins (2).
53. Ejectors (2).
54. Ejector pins (2).
55. Safety crank.
56. Safety-crank stop.
57. Safety-crank stop spring.
58. Safety-crank stop head.
59. Safety-crank stop-head-pin.
60. Safety-crank pin.
61. Safety-crank shaft.
62. Safety-crank shaft lever.
63. Safety-crank shaft-lever spline.
64. Mainspring compressor.
65. Lever and compressor sinks (2).
66. Compressor-sink pins (2).
67. Feed valve.
68. Feed-valve slide.
69. Feed-valve screws (2).
70. Feed-valve lever.
71. Feed-valve lever screw.
72. Feed-valve lever slide.

73. Feed-valve lever abutting (2).
74. Feed-valve lever abutting stay pins (2).
75. Shell deflector.
76. Shell-deflector pins (2).
77. Casing and mount swivel pin.
78. Swivel-pin ring.
79. Swivel-pin ring-chain, and lock pin.
80. Elevating screw.
81. Elevating-screw slide.
82. Elevating-screw slide pin.
83. Elevating-screw slide pin washer.
84. Elevating-screw spoke wheel.
85. Elevating-screw wheel nut.
86. Mount body.
87. Pointing lever and screw.
88. Pointing-lever screw handle.
89. Pointing-lever screw handle pin.
90. Friction plates (2).
91. Friction ring.
92. Friction pin.
93. Mount base.
94. Base hinge ball.
95. Base hinge ball washer.
96. Base hinge ball nut (hex.).
97. Base pivot ball.
98. Base pivot ball nut (hex.).
99. Base pivot ball washer.
100. Base pivot ball split pin.
101. Oscillator.
102. Oscillator nut.
103. Oscillator pin.
104. Oscillator stop screw.
105. Oscillator clamp belt.
106. Oscillator clamp-handle nut.
107. Oscillator clamp bolts stop.
108. Feed guide.
109. Feed-guide catch.
110. Feed-guide catch pin.
111. Feed-guide catch spring.
112. Feed-guide cartridge stops (2).
113. Feed-guide cartridge-stop pin.
114. Cartridge-stop piston.
115. Cartridge-stop piston spring.
116. Cartridge-stop piston pin.

The gun carriage and mount are described as follows:

The carriage of the gun is of new design and construction, and is made entirely of steel and bronze. The frame of the carriage, including the side walls, bed-plate (A), and axle support, is made in one casting. The lunette body and ring, handspike ring and socket, and ground recoil stop support are also in one casting. The top and side trail-plates are supported at their upper corners by angle irons, to which they are riveted. These angle irons extend from the frame to the body, and are riveted to them. Lost motion is prevented in the wheels on the arms of the axles (L) by conical sleeves (L 1) sliding into the boxes (L 2) of the wheels (their ends being cupped to receive the same) against conical washers (L 3) supported by the linch pins (L 4). The sleeves are forced outward by a toggle joint (M) actuated by a hand lever (M 1) (underneath the trail) and can be locked either in or out. Ample compensation is made for wear of surfaces by right and left hand screws (N) locked by jam nuts (N 1). The circular bed-plate (A) of the carriage that supports the swivel-plate (C) of the mount is provided with a taper socket (A 1) to receive the spindle (C 1) of the swivel-plate, which has a circular groove (C 2) into which is inserted by means of a lever (C 3) a sliding bolt (C 4) for holding down the swivel-plate which passes over and around the bed-plate, and may be secured to it in any desired position by the grip ring (C 5), which is fastened in such a manner that it has no movement up or down, while it has ample room to move outward, after being released by the grip-ring screw handle (C 6), and the mount then has full range of the horizon. The base (D) of the mount slips over and around the swivel-plate, and is held from uprising by the nut (D 1) and the lock pin (D 2) on a round bolt (D 3) that passes through the spindle of the swivel-plate. On the upper face of the swivel-plate is a segmental T-groove (C 7) to receive the head of a clamp bolt (C 8) that projects upward through the front of the base-plate. A handle nut (C 9) clamps the parts fast when the oscillator is not in use.

The amplitude of oscillation is 20 degrees, and can be decreased at will by turning the oscillator stop-screw (D 4) on the upper face of the base. From the base-plate projects upward two walls (D 5), forming the outer portion of a joint in which rests the walls (E 1) of the mount body (E). On the inner side of the body are two circular beveled friction-plates (E 2), the outer surfaces of which are forced against the inner sides of the mount; these in turn are forced against the walls of the base, and that is supported by a bolt (E 3) passing through the whole and secured by a washer and nut (F). The friction plates are held from rotary motion by a stout pin (F 1) that passes through the whole. On the friction plates is a grip-ring (F 2), the screw (F 3) of which passes underneath the rear body of the mount far enough to form the pointing lever with its cross-handle (G), thus instantly performing two functions, as the hands do not leave the screw until the gun is pointed and screwed in any position from 30 degrees elevation to 40 degrees depression. At the front of the mount body, extending upward is the arm (H) for supporting the gun-casing (H 1), which is bored for attachment by an ordinary pin-hinge. The mount body extends far enough back to receive the nut (H 5) for the elevating screw (H 2), in the upper part of which is a sliding-box (H 3) to receive the pin (H 4) that makes connection with the rear of the casing.

The caisson that accompanies the gun is of the usual U. S. pattern. The chest is of oak and carries eight (8) ammunition packing drawers, having also sufficient space for appendages and tools. The accompanying drawing (Plate 1) represents one of the eight drawers to be carried in the limber chest. Each drawer holds 45 pasteboard paper-covered cartridge packing cases, which may be made waterproof. Each case holds 20 cartridges. The total amount of ammunition carried in the caisson is 7,200 rounds. The cases are packed on end, and are supported by each other in such a manner that they cannot be shaken around or upturned, and all liability of jamming bullets or shells is prevented. The drawers have on their inside walls a series of grooves, equal in number to one-third of the paper cases to be packed. A movable partition (that can be withdrawn by one motion of the hand) is arranged to fit the grooves. After the drawer has received its full amount of cases the movable partition is inserted into the grooves at the end of the drawer, thereby forming an inner wall, supporting and locking the cases firmly in position. In order to break bulk the partition is removed, thus leaving space enough to admit the fingers to break out the first case, after which there can be no difficulty. When a portion of the cases have been removed from the drawer it is *absolutely* necessary to secure those remaining, and the movable partition can be inserted into the grooves nearest the cases, thus securing them, even to the *last case*, as firmly as though the bulk had not been broken. The partition is secured to the drawer by a stout cord, so that there is no danger of its becoming lost.

The sights used with the gun were an ordinary open breech sight and the Zalinski sight, described in detail in Ordnance Notes No. 188. The latter was presented by the Pratt and Whitney Company as a part of their system, which they wished to test in comparison with the usual sight for their guns.

The experiments were carried on in accordance with the following programme, which was submitted to the representatives of the Gun Company for suggestion:

1. Dismount the gun, separating it into its elementary parts, and reassemble it, this to be done by an expert, and the time to be noted.
2. Fire deliberately 1,000 rounds into a sand butt, determining initial velocities with each kind of cartridge; 500 rounds with the 405-grain bullet and 500 rounds with the 500-grain bullet.
3. Rapidity by an expert, 1,000 rounds; 500 rounds with the 405-grain bullet and 500 rounds with the 500-grain bullet.
4. Rapidity by a non-expert, 1,000 rounds; 500 rounds with the 405-grain bullet, and 500 rounds with the 500-grain bullet.
5. Accuracy of gun and sights at 1,000 yards, 1,000 rounds; 250

rounds with the 405-grain bullet and Zalinski sight; 250 rounds with the 500-grain bullet and Zalinski sight; 250 rounds with the 405-grain bullet and common sight; and 250 rounds with the 500-grain bullet and common sight.

6. Accuracy of gun and sights at one mile, 1,000 rounds; 250 rounds with the 405-grain bullet and Zalinski sight; 250 rounds with the 500-grain bullet and Zalinski sight; 250 rounds with the 405-grain bullet and common sight; and 250 rounds with the 500-grain bullet and common sight.

On May 29, 1884, the gun was taken apart in 46 seconds and reassembled in 1 minute and 27 seconds, by Mr. Smith, from the Pratt and Whitney Company. This was done with deliberation.

The firing then commenced; 6 rounds with the 405-grain bullet giving a mean velocity of 1,300 feet at 50 feet from the muzzle; 6 rounds with the 500-grain bullet giving 1,226 feet velocity at the same distance. Four hundred and ninety-two rounds with the 500-grain bullet were then fired deliberately to try the working of the mechanism; the gun worked well throughout. With the 405-grain bullet in firing 493 rounds deliberately, the working of the crank was interrupted and a cartridge case was found loose in rear of the barrel. There were ten missfires, but nine of these cartridges were subsequently fired. As will be seen by the accompanying firing record there were other interferences with the working of the gun, but they invariably occurred in the left-hand barrel and with the 405-grain bullets. It was discovered that the left-hand lock was slightly worn.

The gun was, at the request of the Pratt & Whitney Company, withdrawn subsequently, and the defect in this lock remedied, after which no obstruction in firing ensued.

The following table briefly summarizes further results which are detailed in the firing record:

Date.	Object.	Number rounds fired.	Time of firing.	
			M.	S.
May 29, 1884	Rapidity by expert	496 500-grain bullet	1	14¼
		496 405-grain bullet	1	9¾
	Rapidity non-expert	498 500-grain bullet	1	29¼
		500 405-grain bullet	3	36¾

In the above rounds 500 cartridges were fed each time, but some of them dropped from the boxes as the attendant was feeding them into the guide. In the last of the series a jam occurred, necessitating the opening of the breech casing and feeding again into the guide a number of cartridges.

Firing to compare the sights and test the accuracy of the gun was then commenced.

Date.	Object.	Kind of cartridge.	No. of sighting shots.	No. of rounds.	Direct hits.	Ricochet hits.
June 3, 1884	Test of Zalinski sight at 1,000-yard target	500-grain	10	250	216	21
		405-grain	54	250	145	14
June 4, 1884	Test of common sight at 1,000-yard target	500-grain	10	250	199	40
		405-grain	4	250	169	39
June 5, 1884	Test of common sight at 500-yard target	500-grain	6	500	470	10
		405-grain	4	500	470	3
July 1, 1884	Test of Zalinski sight at mile target	500-grain	66	250	38	2
		405-grain	72	250	27	3
	Test of common sight at mile target	500-grain	12	250	52	9
		405-grain	12	250	14	1

The firing on June 5 was for the purpose of comparing the gun with its previous record at that distance on January 15, 1880, at which time 500 rounds were fired, giving 447 direct and 14 ricochet hits.

The other firing in the above table served for a comparison of the Zalinski and common sights. Lieutenant Zalinski was present at all the firings when his sight was used and manipulated it himself.

On July 30, 1884, the gun having been previously withdrawn to repair the left-hand lock was returned, and again fired for rapidity. After firing a few rounds the crank-pin came out and the firing had to be resumed. This called attention to a defect which should be remedied. A catch of some kind should be substituted for this pin, as the latter may be loosely inserted, and if lost in action the gun would be temporarily disabled.

The trial was resumed with the following results:

Date.	Object.	Number of rounds fired.	Time.
			M. *S.*
July 30, 1884	Rapidity by expert	500 405-grain bullet	1 11¼
	Rapidity by non-expert	500 405-grain bullet	1 27¾

The 405-grain bullets were all contained in folded head cartridges. The cases were more difficult to extract than those with the 500-grain bullet, and the record shows that they were inferior in accuracy.

The firing records, targets, and drawings referred to are appended.

Summary.—The improved Gardner gun is light, compact, and simple in its structure, and compares favorably with the Gatling gun in everything but rapidity; it fires the service cartridges containing either the 405 or 500 grain bullet equally well. The device for feeding is admirable, and the pasteboard box containing the ammunition for infantry can be easily adapted for use with this gun. This is a great advantage for a machine gun intended to supplement and re-enforce infantry fire. The results obtained with the Zalinski sight do not seem to be sufficiently superior to those with the ordinary sight to compensate for its size and complication.

The recommendation of the Board, made in accordance with the letter of the Chief of Ordnance dated July 25, 1884, is that, as this gun compares favorably with the Gatling gun in everything except rapidity of fire, some of them should be procured for the service, but without the Zalinski sight.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with improved Gardner machine gun at Sandy

[Before firing, the working parts of gun were removed by Mr. Smith, agent of Pratt & Whitney, in 46 sec

	Number of rounds.	Time.		Ammunition.	Elevation.	Instrumental.		
		1884.						
		Month.	Day.				Velocity, feet, 50′ from muzzle.	Time of firing.
					° ′		*Feet.*	*m. s.*
Barometer, 30.079; thermometer, 53; humidity, 49.	1	May.	29	Frankford Arsenal, 500-grain bullet.	0	....	1, 223	....
	1	May.	29		0	....	1, 243	....
	1	May.	29		0	....	1, 226	....
	1	May.	29		0	....	1, 229	....
	1	May.	29		0	....	1, 204	....
	1	May.	29		0	....	1, 229	....
	1	May.	29	Frankford Arsenal, 405-grain bullet.	0	....	1, 307	....
	1	May.	29		0	....	1, 300	....
	1	May.	29		0	....	1, 300	....
	1	May.	29		0	....	1, 290	....
	1	May.	29		0	....	1, 300	....
	1	May.	29		0	....	1, 303	....
	492	May.	29	Frankford Arsenal, 500-grain bullet.	0	....	....	....
	493	May.	29	Frankford Arsenal, 405-grain bullet.	0	....	....	....
	496	May.	29	Frankford Arsenal, 500-grain bullet.	0	By expert....	....	1 14¼
	498	May.	29	Frankford Arsenal, 500-grain bullet.	0	By new hand.	....	1 29¾
	496	May.	29	Frankford Arsenal, 405-grain bullet.	0	By expert....	....	1 9¾
	500	May.	29	Frankford Arsenal, 405-grain bullet.	0	By new hand.	....	8 36¼
Barometer, 29.937; thermometer, 78; humidity, 51.	2	June.	3	Frankford Arsenal, 500-grain bullet.	3 7	....	....	....
	2	June.	3		2 36			
	4	June.	3		2 25			
	2	June.	3		2 27			
	200	June.	3		2 27			
	50	June.	3		2 29			
	2	June.	3	Frankford Arsenal, 405-grain bullet.	2 50			
	2	June.	3		2 40			
	50	June.	3		2 45			
	50	June.	3		2 40			
	100	June.	3		2 37			
	50	June.	3		2 38			

Hook, N. J., from May 29 *to July* 30, 1884.

onds, and replaced in 1 minute 27½ seconds. Gun reported to have been previously fired 16,000 rounds.]

Wind, strength and direction.	From which barrel.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From rear and right, 43°; 31 miles an hour.	Left		Fired into sand butt for velocities.
	Right		
	Left		
	Right		
	Left		
	Right		
	Left		
	Right		
	Left		
	Right		
	Left		
	Right		
	Both		Fired deliberately into sand butt to try working mechanism of gun. Fired deliberately by Mr. Parkhurst, assisted by two other agents of Pratt & Whitney. The gun worked well throughout; but 2 cartridges were thrown to the ground in feeding 494.
	Both		Fired deliberately into sand butt to try working mechanism of gun. Fired deliberately by Pettingill, assisted by two agents of Pratt & Whitney. The working of the crank being interrupted, the casing was opened and locks removed in order to ascertain cause, but without success beyond the fact that it was in left barrel, where an empty case was found hanging in the slot in rear. One cartridge was thrown to the ground in feeding 494, and there were 10 missfires, 9 of which were fired at the second attempt. The lock of the left barrel was then taken out, examined, and oiled.
	Both		Fired into sand butt for rapidity. Served by Parkhurst, Smith, and two assistants. Four cartridges thrown to the ground in feeding 500. Time, 1 minute 14½ seconds.
	Both		Fired into sand butt for rapidity. Served by Merchant, Pettingill (new hands), and two assistants. Two cartridges thrown to the ground in feeding 500. Time, 1 minute 29¾ seconds.
	Both		Fired into sand butt for rapidity. Served by same experts as above. Four cartridges thrown to the ground in feeding 500. Time, 1 minute 9¾ seconds.
	Both		Fired into sand butt for rapidity. Served by same employés of proving ground as above. One stoppage occurred in turning the crank, which was overcome; then came a stoppage which necessitated opening the casing, and an empty case was found sticking in the chamber of the left barrel. After considerable delay in examining the gun and replacing the cartridges the firing was completed, the total time occupied being 3 minutes 36¼ seconds.
From rear and right, 87°; 6.9 miles an hour.	Both.	Lieut. Zalinski's sight.	Sighting shots.
			Fired at 1,000-yard target. Target No. 1. Direct hits, 216. Ricochet hits, 21. Fired in lots of 50, between each of which gun wiped out and oiled.
			Sighting shots.
			Fired at 1,000 yard target. Target No. 2. Direct hits, 148. Ricochet hits, 14. Fired in lots of 50, during one of which a stoppage occurred. The casing was opened, and one empty case was found which had been extracted from the left barrel but not ejected from the gun. Gun wiped out and oiled between the lots.

Record of firing with improved Gardner machine gun at Sandy

	Number of rounds.	Time. 1884.		Ammunition.	Elevation.	Instrumental.	
		Month.	Day.			Velocity, feet, 50′ from muzzle.	Time of firing.
					° ′	*Feet.*	*m. s.*
Barometer, 30.019; thermometer, 78; humidity, 54.	2	June.	4	Frankford Arsenal, 500-grain bullet.	2 32	....	....
	2	June.	4		2 30		
	6	June.	4		2 29		
	50	June.	4		2 32		
	200	June.	4		2 33		
	2	June.	4	Frankford Arsenal, 405-grain bullet.	2 50		
	2	June.	4		2 48		
	250*	June.	4		2 48		
Barometer 30.134; thermometer, 75.3; humidity, 60.	2	June.	5	Frankford Arsenal, 500-grain bullet.	0 30	....	....
	2	June.	5		1		
	2	June.	5		1 10		
	500	June.	5		1 10		
Barometer, 30.103; thermometer, 79.7; humidity, 45.	2	June.	5	Frankford Arsenal, 405-grain bullet.	1 10	....	....
	2	June.	5		1 15		
	500	June.	5		1 15		
Barometer, 29.954; thermometer, 77; humidity, 84.	2	July.	1	Frankford Arsenal, 500-grain bullet.	6	....	....
	2	July.	1		6 15		
	2	July.	1		5		
	12	July.	1		4 45		
	12	July.	1		6 30		
	12	July.	1		7		
	12	July.	1		7		
	12	July.	1		7 12		
	50	July.	1		7 20		
	50	July.	1		7 17		
	50	July.	1		7 15		
	60	July.	1		7 11		
	50	July.	1		7 11		
Barometer, 29.887; thermometer, 75.4; humidity, 81.	12	July.	1	Frankford Arsenal, 405-grain bullet.	9 45	....	....
	12	July.	1		9 15		
	12	July.	1		9 5		
	1	July.			8 50		
	1	July.	1		8 33		
	1	July.	1		8 20		

Hook, N. J., from May 29 to July 30, 1884—Continued.

Wind, strength and direction.	From which barrel.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From rear and right, 43°; 8 miles an hour.	Both.	Open sight.	Sighting shots.
			Fired at 1,000-yard target. Target No. 3. Direct hits, 190. Ricochet hits, 40. Fired in lots of 50, between each of which gun wiped out and oiled.
			Sighting shots.
			Fired at 1,000-yard target. Target No. 4. Direct hits, 169. Ricochet hits, 39. Fired in lots of 50, during which three stoppages occurred, all found to be caused by empty cases jammed in the chamber of the left barrel, from which they had not been extracted. The bullet of a following cartridge was in each case pressing against the head of the empty case.
10 miles an hour. From front and right, 3°.		Open sight.	Sighting shots.
			Fired at 500-yard target. Target No. 5. Direct hits, 470. Ricochet hits, 10. Fired in lots of 50, between which gun wiped out and oiled.
20 miles an hour.			Sighting shots.
			Fired at 500-yard target. Target No. 6. Direct hits, 470. Ricochet hits, 3. Three failures to extract from left barrel occurred during this set, and three failures to eject empty cases, all of which caused stoppages.
From front and right, 3°; 16 miles an hour.		Lieut. Zalinski's sight.	Sighting shots.
			Fired at mile target. Target No. 7. Direct hits, 38. Ricochet hits, 2.
From front; 20 miles an hour.			Sighting shots.

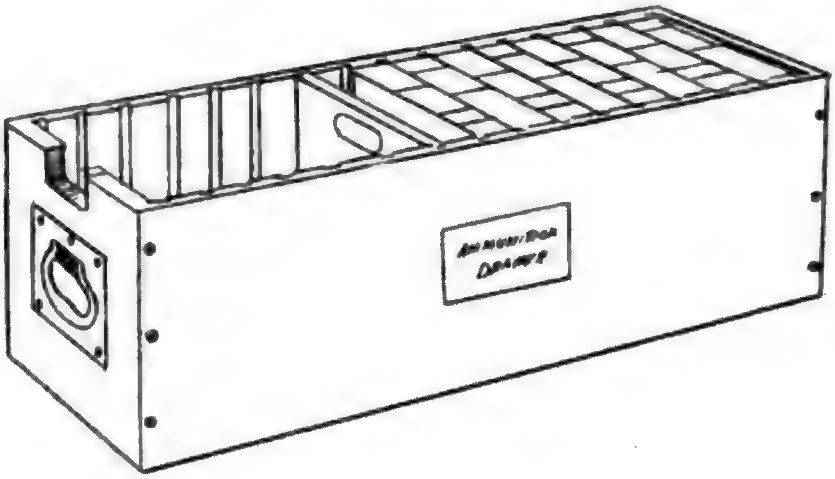
Record of firing with improved Gardner machine gun at Sandy

	Number of rounds.	Time. 1884. Month.	Day.	Ammunition.	Elevation.	Instrumental.		
							Velocity, feet, 50' from muzzle.	Time of firing.
					° ′		*Feet.*	*m. s.*
Barometer, 29.887; thermometer, 75.4; humidity, 81.	50	July.	1	Frankford Arsenal, 405-grain bullet.	8 15	....	....	....
	50	July.	1		8 20			
	50	July.	1		8 25			
	50	July.	1		8 30			
	50	July.	1		8 35			
	12	July.	1	Frankford Arsenal, 500-grain bullet.	7 10	....	....	....
	50	July.	1		7 10			
	50	July.	1		7 15			
	50	July.	1		7 15			
	50	July.	1		7 15			
	50	July.	1		7 15			
	12	July.	1	Frankford Arsenal, 405-grain bullet.	8 39	....	....	....
	50	July.	1		8 39			
	50	July.	1		8 39			
	50	July.	1		8 39			
	50	July.	1		8 39			
	50	July.	1		8 39			
Barometer, 29.818; thermometer, 66.7; humidity, 57.	2	July.	16	Frankford Arsenal, 500-grain bullet.	1 15	....	....	....
	500	July.	16		1 17	By Mr. A. G. Sinclair.	....	1 17
Barometer, 29.870; thermometer, 75; humidity, 69.	65	July.	30	Frankford Arsenal, 405-grain bullet.	0	By expert	....	....
	500	July.	30		0	By expert	....	1 11½
	500	July.	30		0	By new hand	....	1 27½

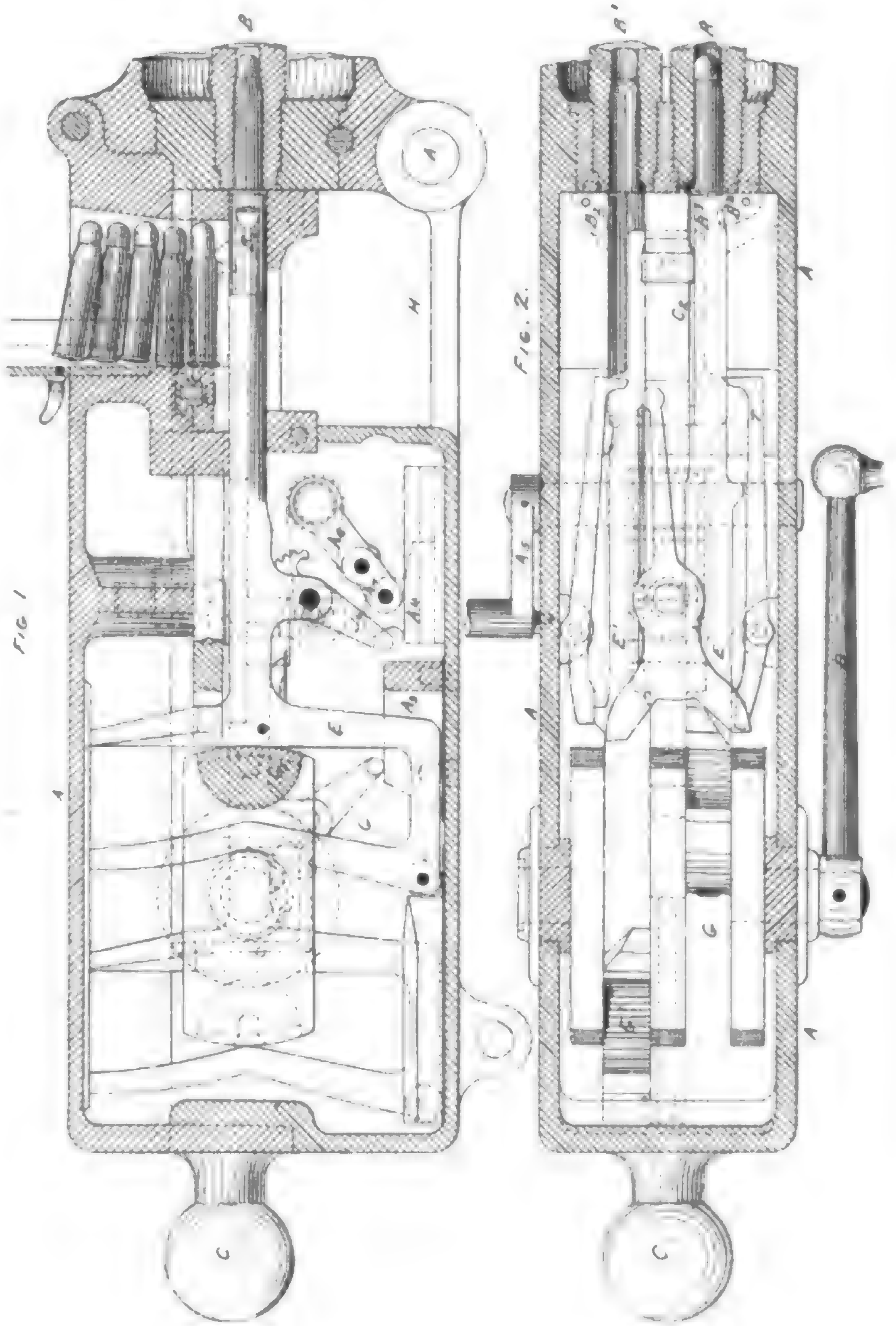
***Hook**, N. J., **from May** 29 **to July** 30, 1884*—**Continued.**

Wind, strength and direction.		From which barrel.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From front; 20 miles an hour.		Both.	Lieut. Zalinski's sight.	Fired at mile target. Target No. 8. Direct hits, 27. Ricochet hits, 3. One miss-fire, which was afterwards fired. Gun wiped out and oiled.
			Open sights.	Sighting shots.
				Fired at mile target. Target No. 9. Direct hits, 32. Ricochet hits, 9
				Sighting shots.
				Fired at mile target. Target No. 10. Direct hits, 14. Ricochet hit, 1.
From rear and left, 3°; 7 miles an hour.				Fired at 600-yard target. Fired for exhibition in presence of the Hon. Secretary of War and party.
From rear and right, 87°; 6 miles an hour.				Fired into sand butt for rapidity. Served by Parkhurst, Pettingill, and two assistants. Crank-pin came out and crank came off; firing ceased until pin and crank were replaced. Served by Parkhurst, Pettingill, and two assistants. Two miss-fires, which were subsequently fired. Time, 1 minute 11¼ seconds. Served by Reilly, Pettingill, and two assistants (new hands). There were 31 miss-fires, all of which were subsequently fired. Time, 1 minute 27¼ seconds.

PLATE I.



Appendix 18—1884



Appendix 18—1884.

Fig. 3.

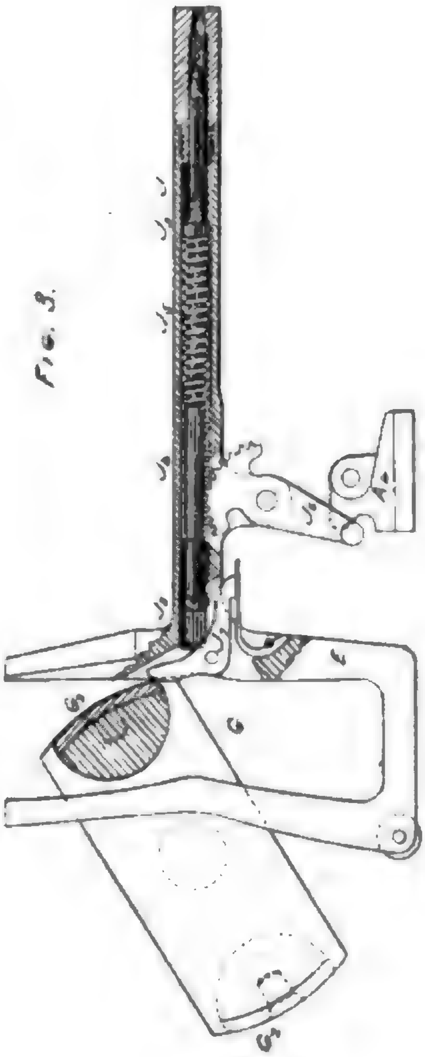
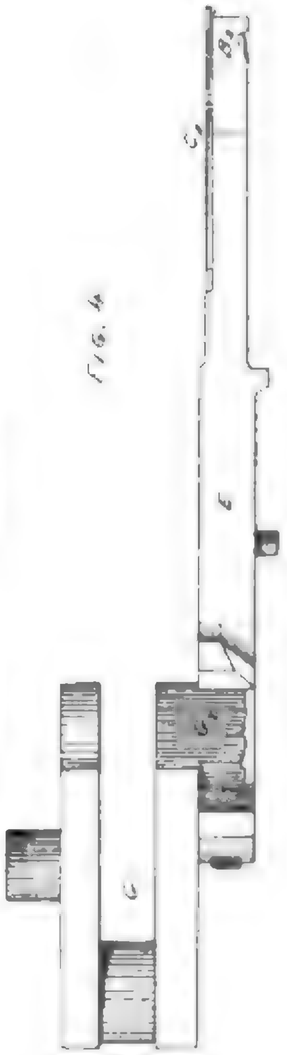
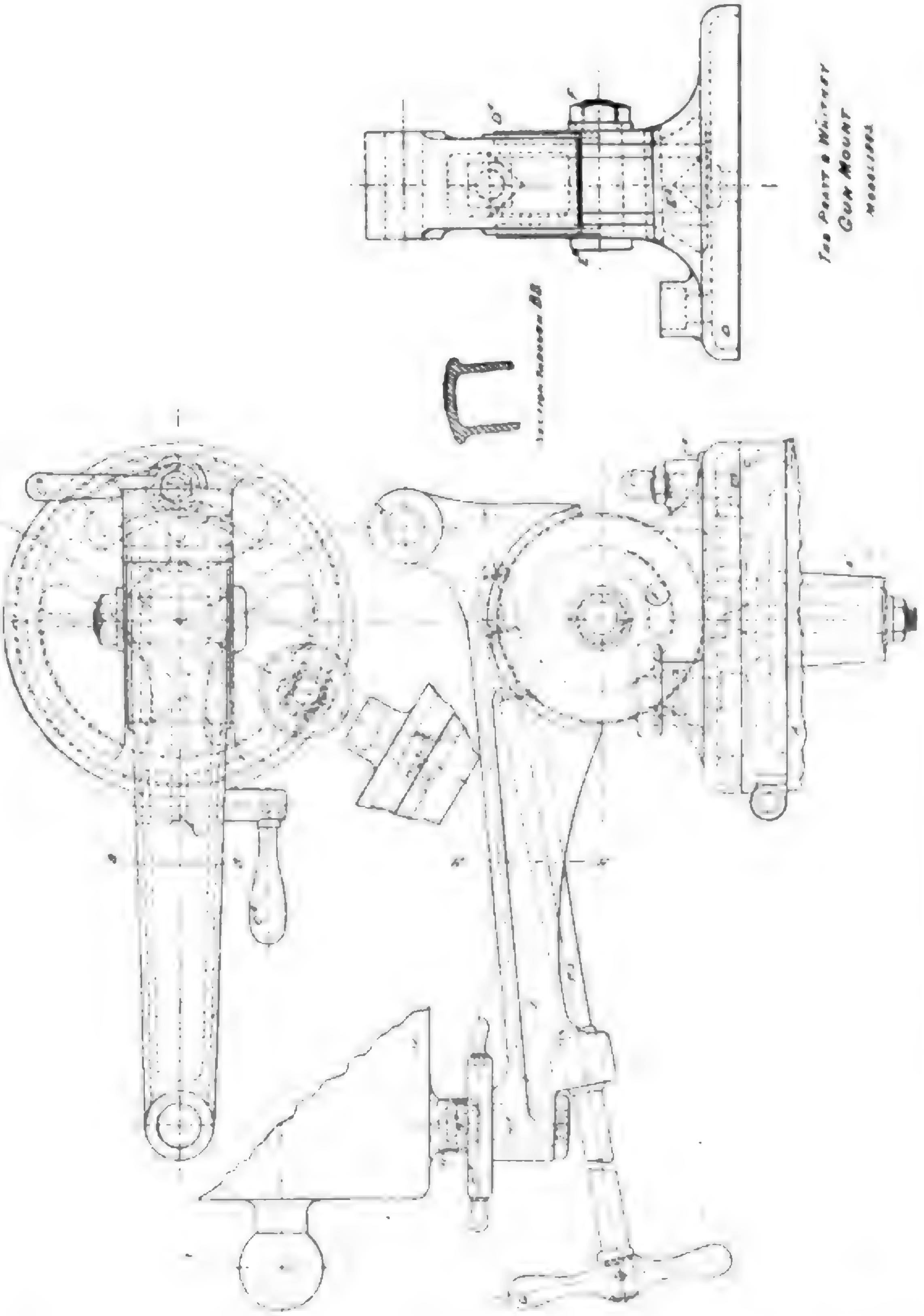


Fig. 4.



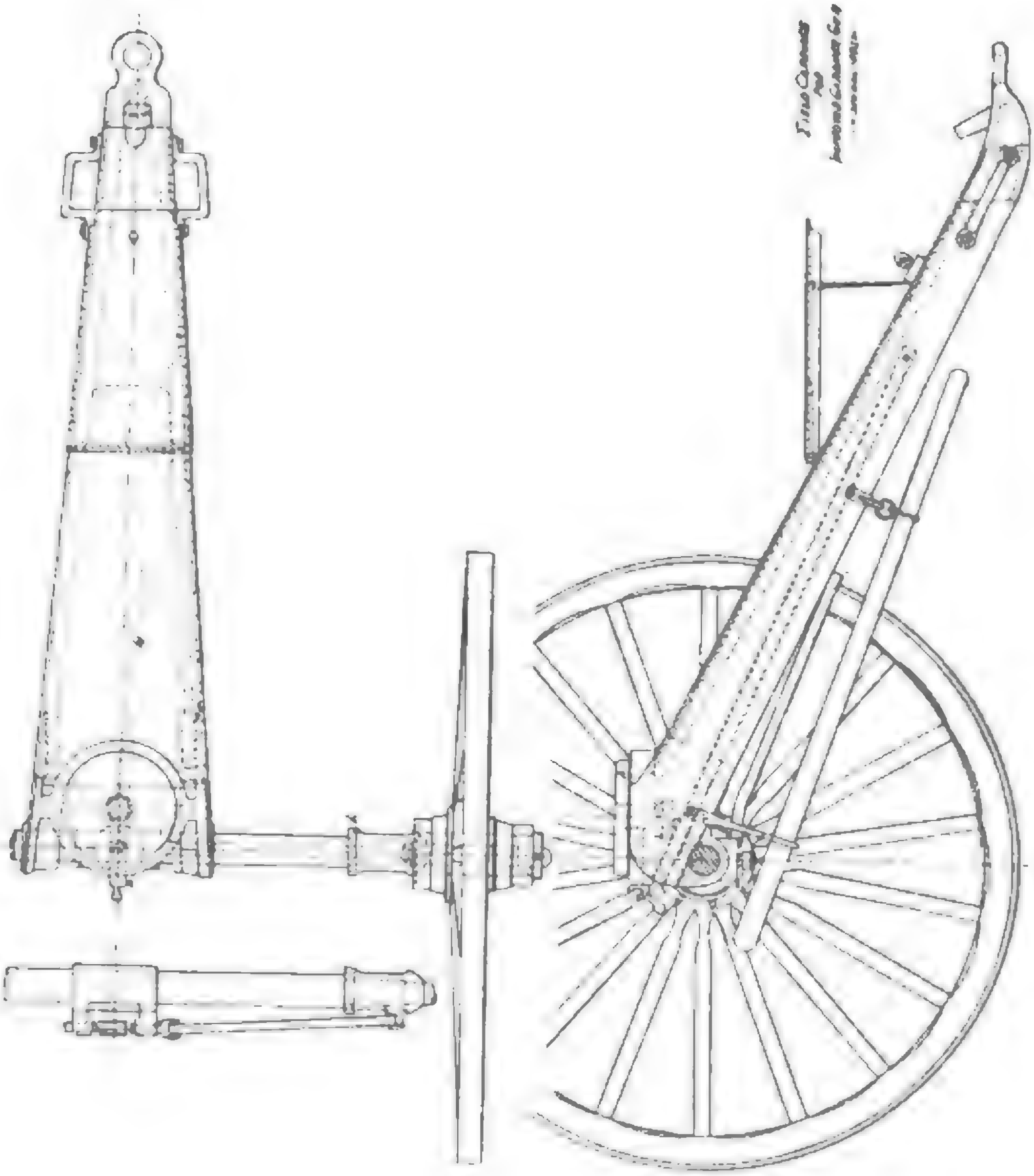
Appendix 18—1884.

PLATE V.



Appendix 18—1884.

PLATE VI.



Appendix 18—1884.

PLATE VII.

TARGET RECORD OF Improved Gardner Machine Gun

June 2. 1884 AT SANDY HOOK, N. J.

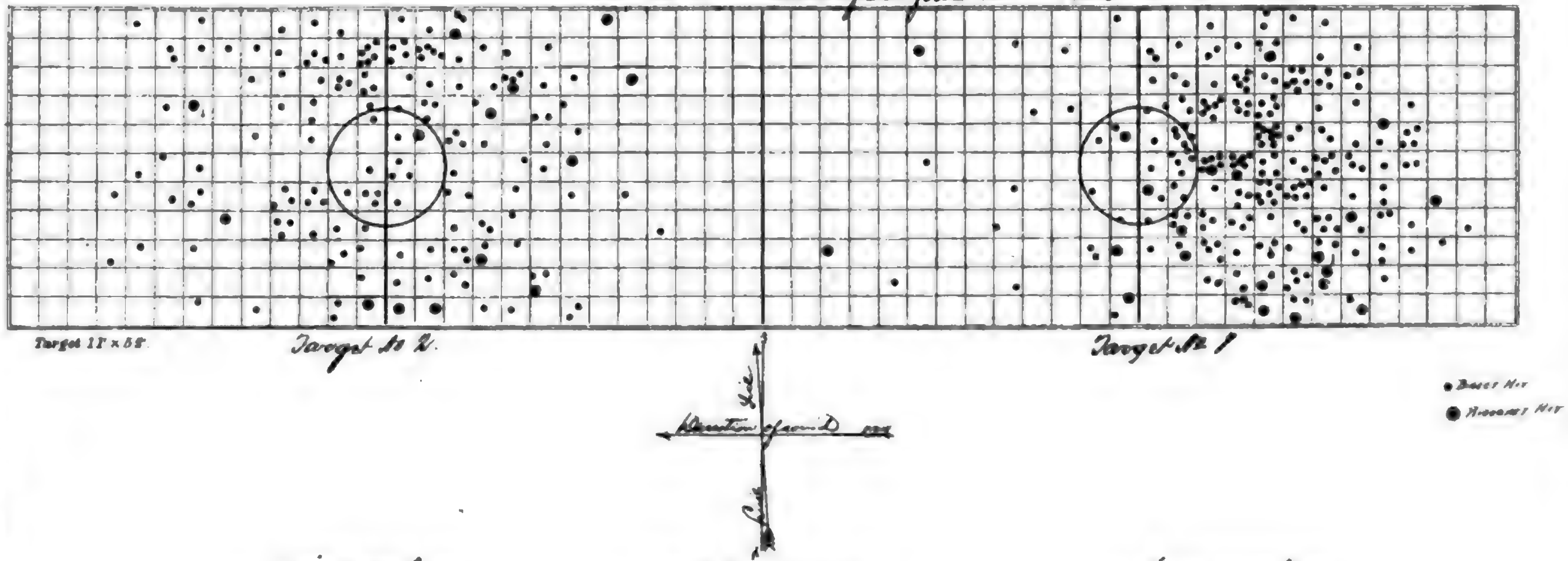
Target 1000 yards from Gun.

Frankford Arsenal 405 grains

Frankford Arsenal 500 grains

Number of shots fired: 250 Direct hits 148 Ricochet hits 14

Number of shots fired 250 Direct hits 216 Ricochet hits: 21



Target 17 x 58.

Wind 6 9 miles per hour.

9 miles an hour

6 miles an hour

Appendix 18—1884.

TARGET RECORD OF *Improved Gardner Machine Gun*

June 4/84 AT SANDY HOOK, N. J.

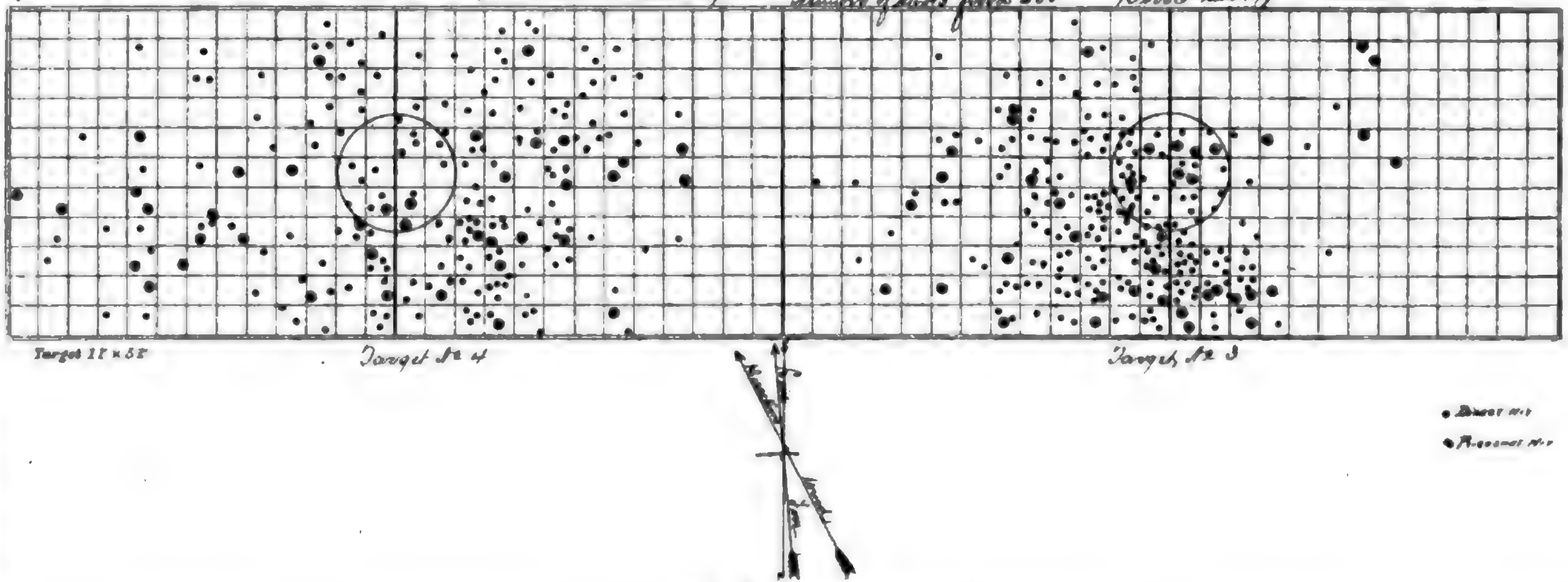
Target *1000 yards* from Gun.

Frankford Arsenal 405 grain

Frankford Arsenal 500 grain

Number of shots fired: *250* *Direct hits 169* *Ricochet hits 39*

Number of shots fired 250 *Direct hits 199* *Ricochet hits 49*



Wind *6* miles per hour.

TARGET RECORD OF Improved Gardner Machine Gun

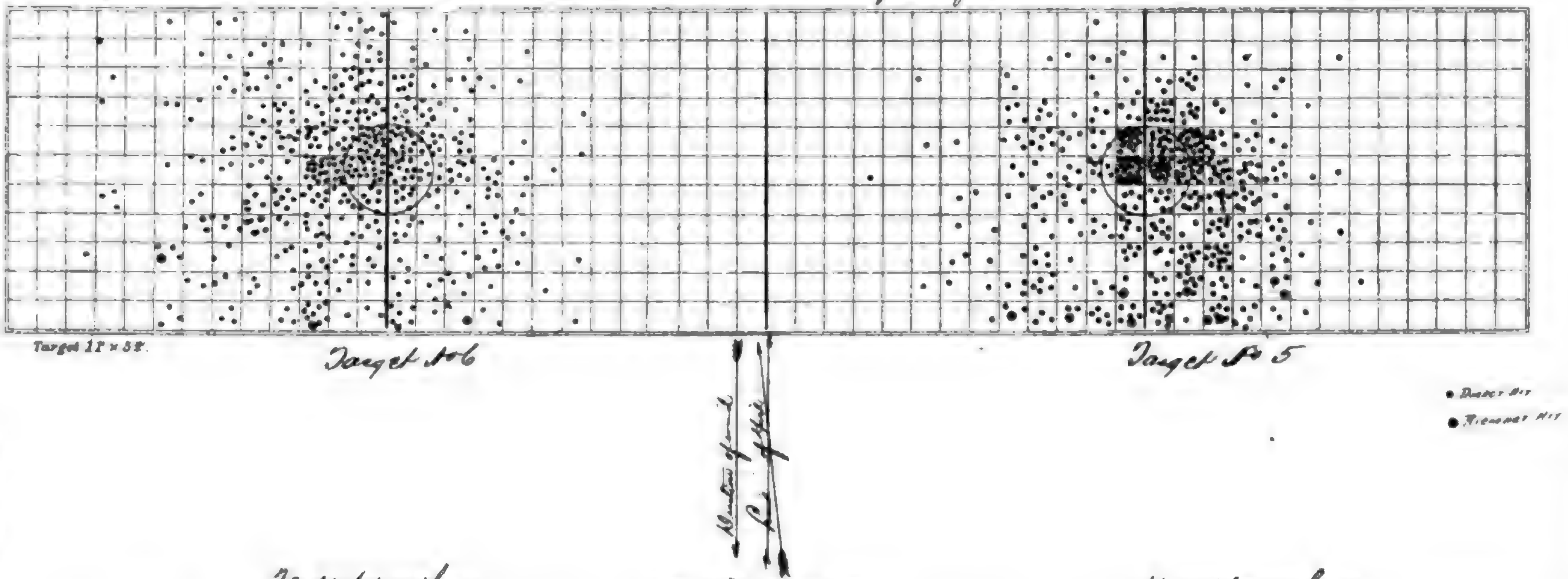
June 5/84 AT SANDY HOOK, N. J.

Target 500 yards from Gun.

Frankford Arsenal 405 grain

Frankford Arsenal 500 grain

Number of shots fired 500 Direct hits 470 Ricochet hits 3 Number of shots fired 500 Direct hits 470 Ricochet hits: 10



20 miles an hour

Wind 10-20 miles per hour.

10 miles an hour

PLATE X

TARGET RECORD OF. Improved Gardner Machine Gun

July 1/84 AT SANDY HOOK, N. J.

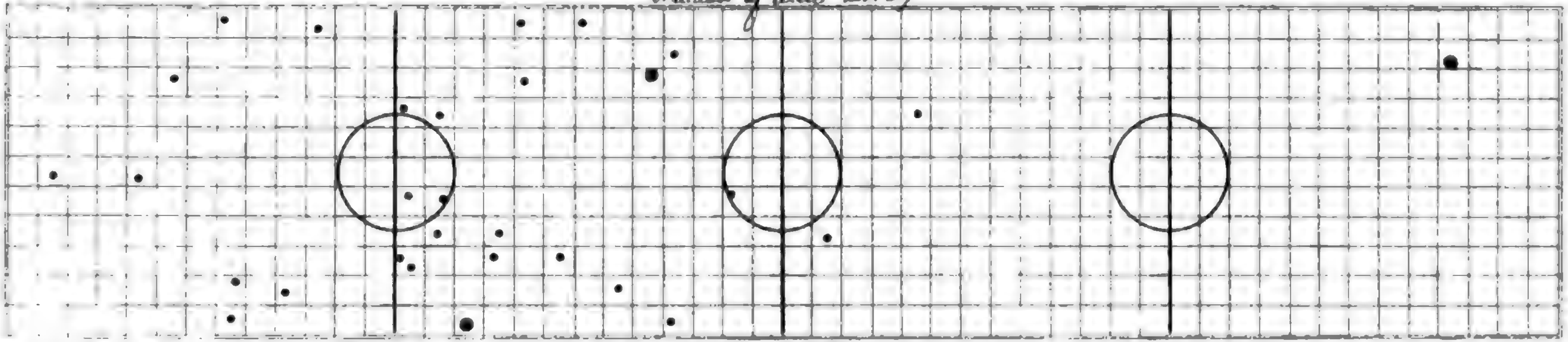
Target One mile - from Gun.

Frankford Arsenal 405 grain bullets

Number of shots fired: 250

Number of direct hits 27

Number of hits: 3 (Ricochets)



Target 11' × 55'

Target #8

Wind 20 miles per hour.

Appendix 18—1884.

TARGET RECORD OF Improved Gardner Machine Gun

July 1/84 AT SANDY HOOK, N. J.

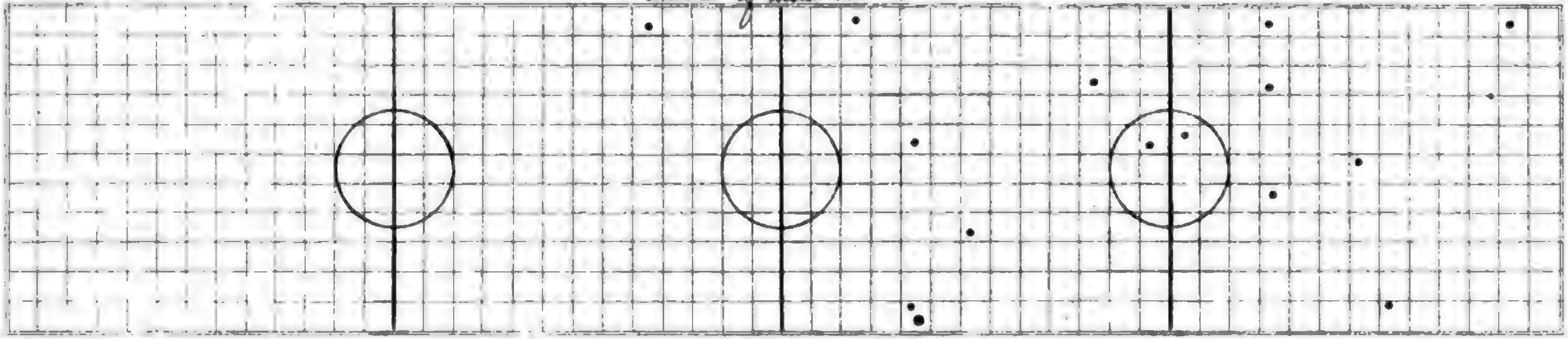
Target One Mile from Gun.

Frankford Arsenal 405 grain Bullets

Number of shots fired 250

Number of direct hits 14

Number of hits: 1 (Ricochet)



Target 11' × 58'

Target #10

Wind 20 miles per hour.

TARGET RECORD OF Improved Gardner Machine Gun

July 1/84 AT SANDY HOOK, N. J.

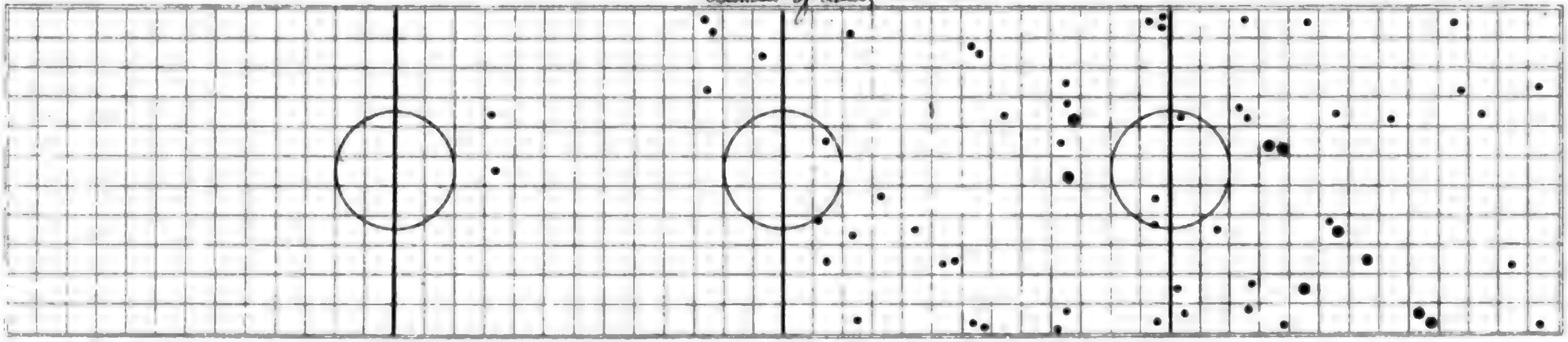
Target One Mile — from Gun.

Frankford Arsenal 500 grains bullet,

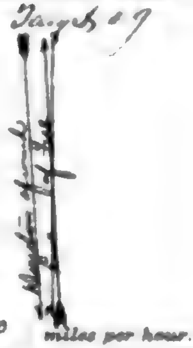
Number of shots fired: 250

Number of direct hits 52

Number of hits: 9 (Ricochets)



Target 11 × 58



Wind 20 miles per hour.

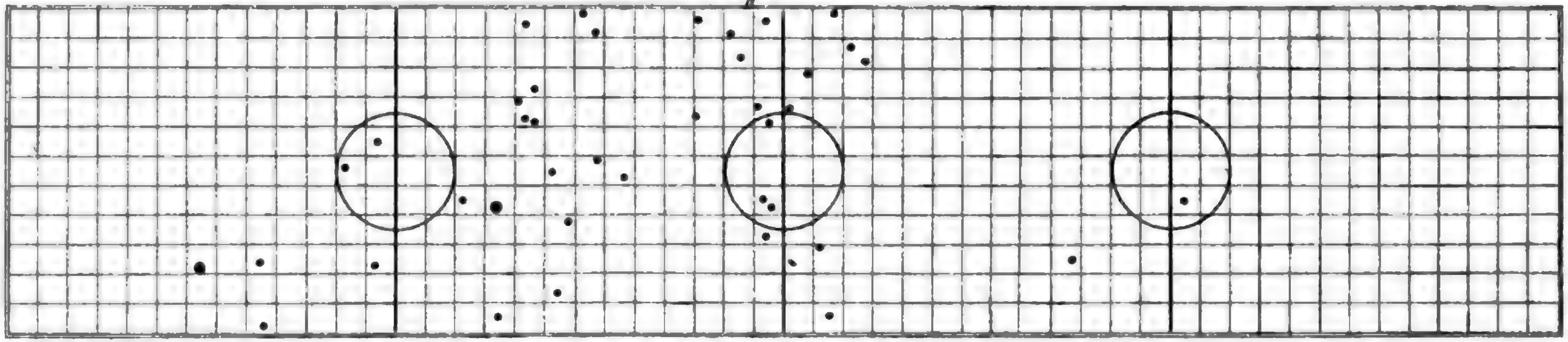
TARGET RECORD OF Improved Gardner Machine Gun

July 1/84 AT SANDY HOOK, N. J.

Target One Mile from Gun.

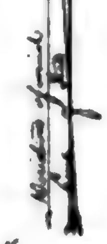
Frankford Arsenal 500 grain bullets.

Number of shots fired: 250 Number of direct hits 38 Number of hits: 7 (Ricochet)



Target 15 × 58.

Angle of 7



Wind 16 miles per hour.

APPENDIX 19.

PROGRESS REPORT ON EXPLOSIVE GELATINE, BY THE ORDNANCE BOARD.

(2 plates.)

On May 25, 1882, a letter was sent to the Chief of Ordnance, stating that General Abbot, United States Engineers, had explained to the Ordnance Board the chemical composition of the explosive gelatine mentioned in his report on submarine mines, and had expressed the opinion that this gelatine, when freshly prepared, could be fired in projectiles from rifled guns without any danger. The Board suggested the trial at Sandy Hook of a few rifle projectiles charged with the gelatine. On May 26, 1882, this letter was returned, indorsed "approved," by the Chief of Ordnance.

On November 10, 1882, a letter from Commodore Montgomery Sicard, Chief of Bureau of Ordnance, Navy Department, was referred to the Ordnance Board in an indorsement by Chief of Ordnance, United States Army, stating that "75 pounds of explosive gelatine had been ordered to be sent to the Sandy Hook Proving Ground."

This gelatine was delivered at Sandy Hook on the 15th of March, 1883. The Board, having been notified that it would arrive on that day, reached the Hook about one hour after the delivery of the explosive, as it was deemed expedient to commence experiments with it as soon as possible. The gelatine was found to be frozen, and so hard that it could with difficulty be penetrated with a knife. All the details of the experiments with it are given in the accompanying firing record.

In a letter of April 3, 1883, from Capt. Thomas O. Selfridge to the president of the Board, it is stated that this gelatine was made on the 9th of December, 1882, and that its composition was as follows:

	Per cent.
Nitro-glycerine	88.66
Soluble gun-cotton	7.34
Camphor	4.00
	100.00

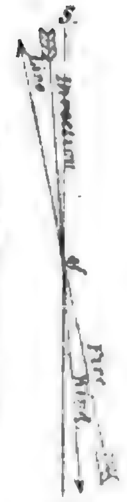
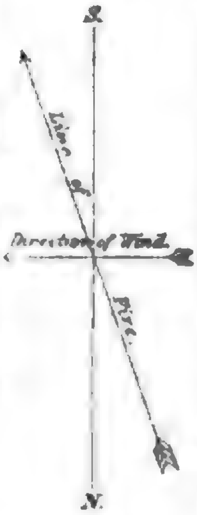
It will, therefore, be seen that this gelatine was over three months old when it was received by the Board, and that the circumstances attending the experiments with it were not those contemplated by the Board originally. For, as mentioned above, General Abbot stated that he believed it would be entirely safe to fire it in shells from rifled guns when it was freshly prepared.

It is, of course, understood this or a similar explosive would only be used in time of actual war. In so far as the specimen tried by the Board is concerned it was shown that, although old, it possessed great stability and was with difficulty detonated. It would appear that the detonation is more perfect when the gelatine is exploded in a solid mass and not cut up into strips or cubes. A shell with the base screwed on could be readily devised to contain cylinders of this gelatine freshly prepared to be used in time of war.

Finally, it is respectfully suggested that the Board be authorized to prepare a small quantity of this compound and fire it in shells from rifled guns.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with explosive gelatine, at Sandy

		Number of fire.	Powder.		
			Time.	Kind.	Weight.
			1883.		*Lbs.*
			Mar. 16	....	......
Barometer, 29.934; thermometer, 31; humidity, 68; wind, 24 miles an hour.	In 3″ M. L. rifle. No. 905.				
		783	Mar. 16	Mortar	1
		784	Mar. 16	Du Pont's I. K. A.. Density, 1.725; granulation, 2,200.	3
			Mar. 16		
			12 pounds explosive gelatine frozen; 1 cake.		
Barometer, 29.939; thermometer, 37; humidity, 46; wind, 16 miles an hour.	In 3″ M. L. rifle, No. 905. 	785	Mar. 28	Du Pont's I. K. B. Density, 1.725; granulation, 2,200.	3
		786	Mar. 28		3
		787	Mar. 28		3
		788	Mar. 28		3
		789	Mar. 28		3
		790	Mar. 28		3

NOTE.—Gelatine when first taken from the box in which it arrived was found to be frozen and ex
ping a 12-pound rifle projectile point on through a height of 3′, projectile merely denting the cake at
grees Fahrenheit some 16 hours, when it was found that the cake was so much softened as to be easily
the fuze hole of the shell when loading.

Hook, N. J., from March 16 to March 28, 1883.

Projectile. Kind.	Weight.	Elevation.	Recoil.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
	Lbs.	° ′	*Feet.*	
Butler shell (old), containing 6 pounds explosive gelatine.	144	......	......	Placed on a block point on and close to an iron plate 4″ thick and 6′ wide and 12′ long, and exploded by means of 1 electric primer (fulminate). Explosion reduced shell to a great number of small fragments, throwing some of them over the sand butt, behind which the plate was placed, and to the front. After explosion at least one-third of the pieces of the gelatine which were put in the shell were found scattered in the sand unconsumed. Effect on plate, slight depression.
Dyer percussion shell with Schenke percussion fuze. Shell containing 6¼ ounces explosive gelatine.	9	......	......	Fired at iron plate. Shell found at plate, broken into very small fragments. Plate spattered with lead from sabot. Indentation slight.
	9	......	......	Fired at iron plate and through a wooden screen placed between gun and plate. Shell broke up at or near muzzle.
Butler shell (old), containing 3 pounds, 12¼ ounces explosive gelatine.	144	......	......	Placed on a block side on and in contact with iron plate and exploded by means of 3 electric primers (fulminate). Explosion; shell broke into many small fragments. Effect on plate slight.
......	......	......	......	Placed flatwise against face of plate. Exploded by means of 3 electric primers (fulminate). Effect, crack made in plate 2¼″ long. Depression made 2″ deep.
Dyer's percussion shell with Schenke percussion fuze. Shell unfilled.	9	5	21	Fired over water. Flight good; did not break up.
	9	5	22	Do.
	9	5	22	Sabot stripped. Did not break up
Shell containing 6¼ ounces explosive gelatine. Plunger removed from fuze.	9	5	22.50	Burst at or near muzzle of gun.
	9	5	23.50	Do.
	9	5	23	Do.

ceedingly difficult to cut with a knife. An effort was made to break one cake of 12 pounds by drop
its fall. It was then placed in an old bomb-proof and kept at a temperature of between 60 and 70 de-
cut with a knife, when it was cut into strips and cubes sufficiently small to enable them to go through

On January 26, 1884, the Board wrote the Chief of Ordnance stating that General Abbot, United States Engineers, had on hand a quantity of improved explosive gelatine, and requesting that authority be obtained from the Engineer Bureau, War Department, for General Abbot to furnish the Board with 50 pounds of that explosive.

Authority having been granted, experiments were conducted at Sandy Hook on February 26, 27, and 28, and March 8. Full details are given in the accompanying firing records.

The explosive gelatine was manufactured by the Nobel's Explosive Company, Glasgow, Scotland. It is put up in cartridges about 3.5 inches in length by 0.75 inch in diameter. The cartridge paper is a strong white fabric and may be easily detached from the gelatine. Each cartridge is labeled "Dynamite." The gelatine is of the consistency of the ordinary fruit pastes, which it much resembles in appearance. It is readily cut with a knife, and may be torn or shredded with the fingers. Hence the shells were easily loaded and the charges made very compact by hand. General Abbot informs the Board that the chemical composition of this sample is as follows:

	Per cent.
Nitro-glycerine	92
Nitro-cotton	8
	100

It will be seen that there is no camphor present here. General Abbot states that 7 to 10 per cent. of camphor will render the gelatine entirely inexplosive, and that the Austrians camphorate their war gelatine to the extent of 4 per cent.

On February 27 one shell loaded with gelatine having been fired successfully from a 3-inch muzzle-loading rifle, it was thought that possibly the premature explosions might be due to heat generated by the angular velocity of the shells. It was therefore determined to load the gelatine into wooden cases, the gelatine being very compact with the case and revolving with it. It was attempted to make the friction a minimum by lubricating the case with paraffine and graphite.

As shown in the records, the first shell thus prepared was fired successfully from a 3.2-inch breech-loading rifle. The shell passed through a wooden target composed of 2-inch boards, and exploded after striking a second target of iron.

In the second shell the wooden case became cracked while being loaded. This may or may not have caused the premature explosion.

There seems to be little doubt as regards the third shell that it either broke from the shock of discharge or admitted powder gas, thus detonating the gelatine instantly near the seat of charge.

The shells used in the trials were of the Butler pattern for muzzle-loaders and Hotchkiss for breech-loaders, altered in the best manner possible to suit the occasion.

As detailed in the records, three shells were fired with fulminate of mercury fuzes. The fulminate was too sensitive to stand the shock, and it was found afterwards that the gelatine needed no detonator.

Although the tests made were few, it would nevertheless appear from them—

1. That the shells explode after clearing the muzzle, and therefore the detonation of the gelatine is due to some cause other than the shock of discharge—very possibly the heat generated by angular velocity.
2. This is corroborated by the fact that one shell passed through a 2-inch board target without explosion.

3. The gelatine used in these tests not being camphorated renders it highly probable that a certain percentage of camphor added would establish a compound which could be fired successfully in a specially constructed shell.

4. The gelatine does not require a fuze or detonator of any kind.

5. It is believed the shell which destroyed the 3.2-inch breech-loading gun broke from the shock of discharge or admission of powder gas, and thus detonated the gelatine.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 3-inch muzzle-loading rifle No. 965, at Sandy

	Number of fire.	Time.	Powder. Kind.	Powder. Weight. lbs.	Powder. Weight. oz.	Projectile. Kind.	Projectile. Weight. lbs.	Projectile. Weight. oz.	Elevation. °	Elevation. '
		1884.								
Barometer, 29.804; thermometer, 38; humidity, 82.	791	Feb. 26	Mortar	1	4	Butler shell (empty).	9	4	0	
	792	Feb. 27	do	1	4	Butler shell	10	...	+¼	
	793	Feb. 27	Du Pont's I. K. B. Density, 1.725. Granulation, 2,200.	2	...	do	10	4	+¼	
	794	Feb. 27		2	...	do	9	12	+¼	
	795	Feb. 27		2	...	do	9	...	+¼	
Barometer, 29.913; thermometer, 40, humidity, 73.	796	Feb. 27		2	...	do	9	12	+¼	

Hook, N. J., from February 26 to February 27, 1884.

Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From rear and left 48°, 11 miles an hour.	Fired into sand butt to try fuze	Fuze contained 25 grains fulminate of mercury. Fuze exploded on striking butt.
From rear and right 88°, 12 miles an hour.	Fired at iron target 70 yards from muzzle of gun to try fuze.	Shell loaded with a bursting charge of 10¾ ounces musket powder. Fuze contained 25 grains fulminate of mercury. Shell exploded at or near muzzle of gun.
	Fired into sand butt No. 2 to try fuze	Shell loaded with a bursting charge of 11 ounces musket powder. Fuze contained 25 grains fulminate of mercury. Shell exploded at or near muzzle of gun.
	Fired at iron target 70 yards from muzzle of gun to ascertain if shock of firing would explode gelatine.	Shell loaded with explosive gelatine (¾ pound), using a Hotchkiss fuze with plunger removed. Shell exploded at or near muzzle of gun.
	Fired at iron target 70 yards from muzzle of gun to ascertain if shell would break up by shock of discharge.	Shell empty and plugged with wood. Shell struck target before breaking up.
	Fired at iron target 70 yards from muzzle of gun to ascertain if shock of firing would explode gelatine.	Shell loaded with ¾ pound gelatine, using a Hotchkiss fuze without plunger. Shell exploded on striking target. A wad of tow half filling a 3-inch cartridge bag was interposed between shell and cartridge. The shell struck target sideways, producing an appreciable indentation. The heads of the shells used in these rounds were screwed to the body for the sake of convenience in introducing the gelatine.
		The gelatine sticks (in paper wrappers) were loaded in the shell as compactly as could be done by hand, and the head of the shell was filled with cotton waste.

Record of firing with 3.2-inch breech-loading rifle No. 774,

CHAMBERED.

	Number of fire.	Time.	Powder.			Projectile.			Elevation.
			Kind.	Weight.		Kind.	Weight.		
				lbs.	oz.		lbs.	oz.	° ′
Barometer, 29.231; thermometer, 37; humidity, 82.	878	1884. Feb. 28	Du Pont's I. K. B. Density, 1,725. Granulation, 2,200.	2	....	Hotchkiss shrapnel case filled with 1 pound explosive gelatine.	11	....	+½
Barometer, 29.941; thermometer, 35; humidity, 89.	879	Mar. 8		2	....	Hotchkiss shrapnel case filled with 1 pound explosive gelatine, contained in wooden case.	10	8	+13′
	880	Mar. 8		2	....		10	8	+15′
	881	Mar. 8		2	....		10	8	+15′

at Sandy Hook, N. J., from February 28 to March 8, 1884.

CHAMBERED.

Wind, strength and direction.			Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
From rear and right 43°, 28 miles an hour.		Fired at iron target, distant 70 yards from gun, to ascertain if shock would explode gelatine. Shell exploded at or near muzzle of gun. Gelatine packed in shell as compactly as possible by hand. Paper coverings removed from sticks of upper layers and head filled with cotton waste. A tow wad was inserted between base of shot and cartridge.	
From front and left 40°, 6 miles an hour.	Burst on striking target.	Fired at iron target, distant 70 yards from gun, to ascertain if shock of firing would explode gelatine. Gelatine packed in an inner wooden case as compactly as possible by hand. Paper coverings removed from sticks of upper layers and head of shell filled with cotton waste. A tow wad was inserted between face of shot and cartridge. The inner case was of pine wood and was so fitted to the cavity of shell as to admit free motion within it. Walls of cavity and inside and out of wooden case smeared with paraffine and black lead.	Shell passed through wooden screen 2 inches thick without bursting.
	Burst at or near muzzle.		Burst in gun. All that part of gun in rear of front of breech-receiver was thrown uninjured to the rear, and the rest of the gun was broken into six large fragments. The carriage was dismounted, both wheels entirely disabled, cheeks spread outward forward of the front transom 90 degrees, reinforcing cheek and trunnion bed-plates broken.

The Ordnance Board respectfully submits the following report of its investigations up to date in the matter of high explosives, it being thought that the experience and information thereby attained might be of service to others interested in the subject, and that it might possibly prevent them from going over old ground.

The Board on April 7, 1883, forwarded Ordnance Board Report No. 6, 1883, accompanied by firing records, giving all the details of experiments with explosive gelatine furnished by the Navy Department. On March 15, 1884, Ordnance Board Report No. 19, 1884, was forwarded with firing records, giving details of the experiments up to that time with explosive gelatine, furnished by Colonel Abbot, of the United States Corps of Engineers.

On March 29, 1884, the following letter was forwarded:

> In the reports already forwarded of the experiments made at Sandy Hook with explosive gelatine it has been shown that it is possible to fire this compound successfully from a rifled gun. The shells used were not specially devised for this explosive, but were cast-iron projectiles, reamed out in some instances, in others cut in two so as to form a screw-head. They were, consequently, not entirely suited for the purpose, but the results from such improvised material are at least encouraging.
>
> There are available for experimental purposes guns which have reached their anticipated life period (in the service), and others which have been injured in the experimentations directed to be made with the devices of various inventors. One 8-inch muzzle-loading gun at Sandy Hook is so injured and would answer for this purpose.
>
> The experiments would not be very costly, and, if successful entirely, the enormous pecuniary value of them to the United States certainly warrants a determined and fair trial in this direction.
>
> It is recommended that a special shell, drawings of which will be forwarded, be constructed, and that a certain quantity of camphorated gelatine be obtained from the Nobel Company.
>
> It is understood that the Nobel gelatine recently used, and which was fired successfully in two shells, was the ordinary blasting dynamite, and had no camphor in it. Its composition has been given in the report.
>
> The Board will get all possible information from Nobel and make experiments looking to the camphorating of the gelatine on hand with as little delay as possible, of which you will be promptly notified.

The Board, as appears from this communication, requested authority from the Chief of Ordnance to have special cast-iron 8-inch shells constructed. Detailed drawings of these shells were forwarded April 7, 1884. The solid head was screwed on, but the object was simply to demonstrate the possibility of firing gelatine from a gun. The solid head would help to show what penetration, if any, could be obtained in a wrought-iron target before the gelatine was detonated by concussion. This cast-iron shell was necessarily weak at the screw circumference. Should this experiment be successful the Board proposed to design a steel shell with the screw at the base and a head constructed in the best known manner for penetration into armor-plates. The details of the trials with these 8-inch cast-iron screw shells are given in the accompanying firing records.

They were sufficiently successful to warrant the Board in suggesting six steel shells to be made. The letters and drawings there anent were forwarded to the Ordnance Office on August 16, 1884.

The Board desires to state that a rubber buffer, suggested by Mr. F. H. Williams, of Syracuse, N. Y., and described in the firing records, has heretofore been used in these trials, but it is believed that the gelatine may quite probably be fired without any cushion whatever. It is also believed that paper cases for containing the explosive may be dispensed with. The diaphragm at right angles (described in records) is thought to be necessary, or at least safe, in a rifle shell.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 8-inch muzzle-loading rifle No. 7, B. I.,

	Number of fire.	Time.	Powder.		Projectile.		
			Kind.	Weight.	Kind.	Weight.	
		1884.		*Pounds.*		*Lbs.*	*Oz.*
Barometer, 30.012; thermometer, 79.3; humidity, 43.	424	June 18	Du Pont's sphero-hexagonal K. H. B. Density, 1.775; granulation, 123.	40	Paper case empty ...	1	2¾
					Paper case filled	4	4½
					Shell empty	154	0
					Total weight........	158	1½
Barometer, 29.850; thermometer, 72.2; humidity, 60.	425	July 8	....do	40	Paper case empty ...	1	2[illegible]
					Paper case filled.....	6	5[illegible]
					Shell empty with cork	153	14
					Rubber	8	5
					Cork		1¼
					Weight of gelatine ..	5	3[illegible]
					Total weight of shell filled.	160	3[illegible]
Barometer, 29.850; thermometer, 72.2; humidity, 60.	426	July 8	....do	40	Paper case empty ...		15[illegible]
					Paper case filled	6	14[illegible]
					Shell and cork........	154	1½
					Weight of gelatine..	5	14[illegible]
					Total weight of shell filled.	161	0[illegible]
Barometer, 29.839; thermometer, 77.8; humidity, 58.	427	July 10	....do	40	Paper case empty ...	1	2
					Paper case filled	6	12½
					Shell and cork	154	1½
					Cork		1½
					Weight of gelatine..	5	10½
					Total weight of shell filled.	160	14
Barometer, 29.970; thermometer, 73.2; humidity, 83.	428	Aug. 23	....do	40	Shell empty	157	7
					Shell filled	166	4
					Gelatine.............	8	13
					Kubber	8	0

at Sandy Hook, N. J., from June 18 to August 23, 1884.

Elevation.	Pressure, per square inch of bore. Rodman.	Instrumental velocity, feet; 90′ from muzzle.	Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
° ′	*Pounds*	*Feet.*	*Feet.*			
0	27,000	1,397	......	From front and left 43°, 24 miles an hour.	Fired into sand butt.	Gun mounted on cradle. Shell specially prepared with detachable head for explosive gelatine, containing a paper case ⅛-inch thick divided longitudinally in four sections by wooden partitions ⅛-inch thick intersecting each other at right angles. Laundry soap, cut into strips and wrapped in soft paper in imitation of explosive gelatine, was packed in carefully by hand, and the case was then inserted into the shell, resting at bottom on cotton waste. When recovered and examined the base of the paper case was found crushed in on one side, and the side was split in one place longitudinally. All the wooden partitions were broken off where attached to paper case. The soap was compressed only to the extent of making it difficult to distinguish and separate the sticks. A hollow rubber buffer 1″ thick, 6″ long, and 6″ in diameter, inserted between the charge and projectile, was considerably broken up at the discharge.
16	26,000	1,360	22.00	From front and left 87°, 2 miles an hour.	Fired at iron target, distant 383′ from gun, consisting of 10″ of iron backed by 30″ of oak, previously used in experiments with 15″ S. B. gun.	Shell specially prepared, as in round 424, with paper case (subdivided as before into four vertical sections by thin wooden diaphragms, extending, however, only to within ⅜ inch of bottom) resting on cork, filling bottom of shell cavity. A rubber buffer was also interposed between cartridge and shell, as in round 424. The interior of shell, the cork, and surfaces of paper case were carefully smeared with plumbago, and the explosive gelatine filled in compactly without removing paper from sticks. Small wads of waste were placed underneath and above the gelatine. The shell burst into small fragments after striking target. The head, a large portion of which was found in front of target, had penetrated to a depth of about 7 inches, leaving a fair impression, on the right side of which the outer 2″ plate of target was somewhat cracked.
14	25,500	Frames demolished and records entirely unreliable.	18.00			Shell prepared and fired as in preceding round, except that the wooden partitions were omitted and that the interior surface of the paper case was not coated with plumbago. Shell burst at or near muzzle with so little comparative violence that large pieces of the paper case—the bottom almost entire—were picked up between gun and target. A portion of the base of shell, carrying about two-thirds of the sabot, struck target-making well-marked indentation.
14	19,900	....	13.00	From front and right 3°, 18 miles an hour.		Shell specially prepared and fired as in round 425, except that the gelatine in each partition was covered with pasteboard discs. Shell burst into small fragments after striking target, making penetration of 7 inches.
14	22,000	....	13.00	From rear and left 3°, 3 miles an hour.	Fired at iron target, distant 353 feet from gun, and shell exploded on impact.	Shell divided into 4 longitudinal sections by diaphragms of sheet copper and gelatine packed in by hand, a small pad of cotton waste being placed at bottom and top.

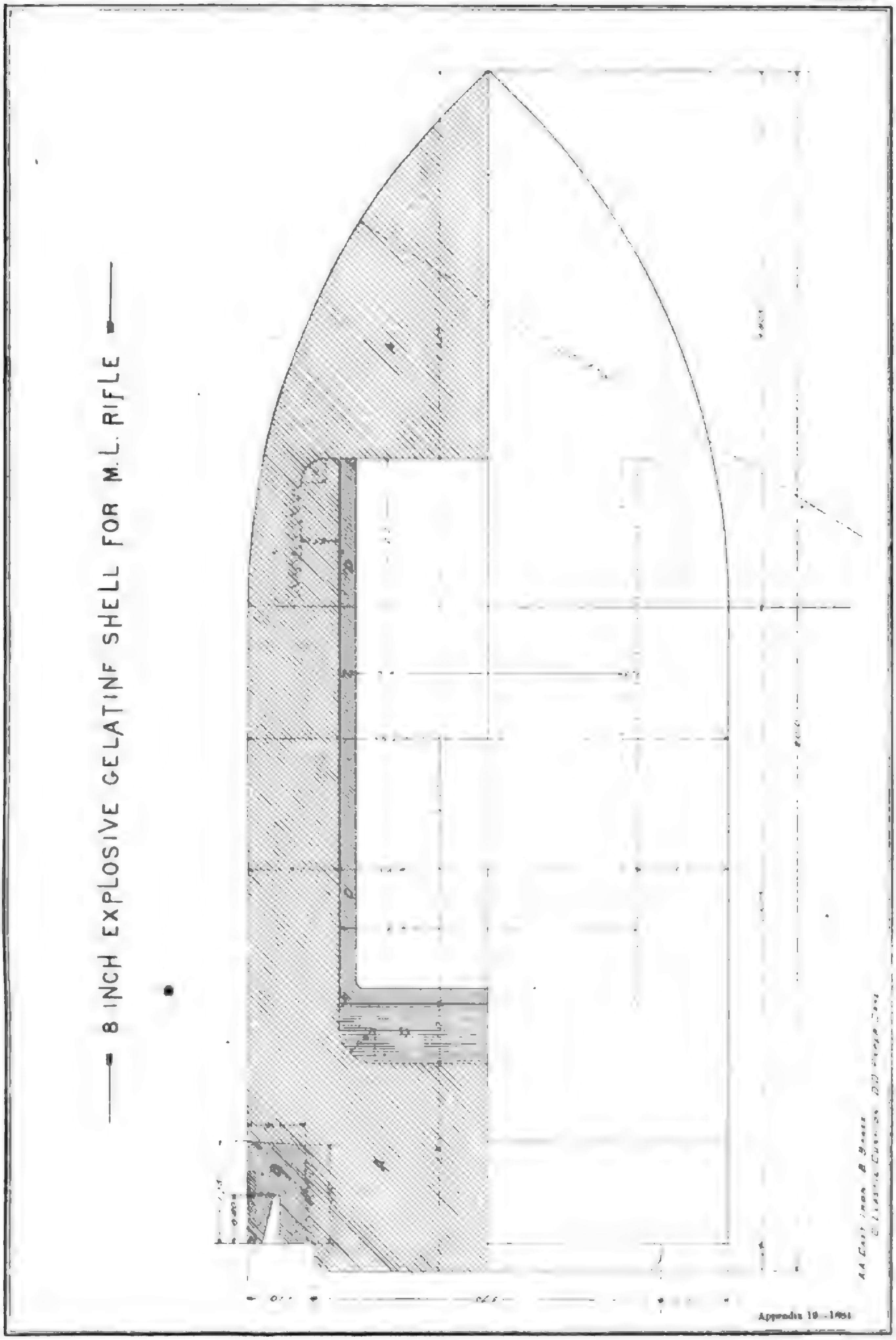
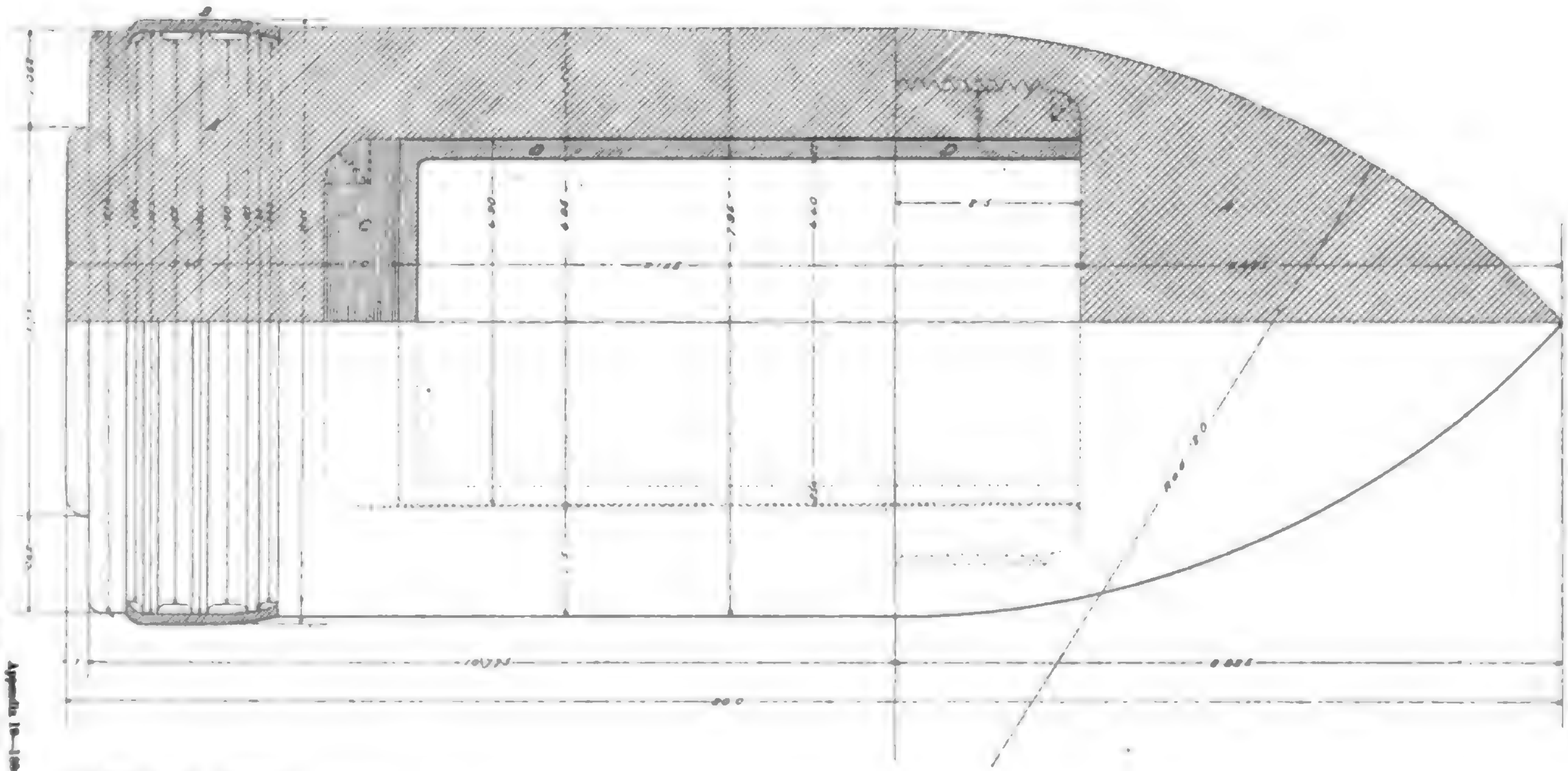

8 INCH EXPLOSIVE GELATINE SHELL FOR M.L. RIFLE
A
A
B
C
D
D
A A Cast iron B Brass
C Elastic Cushion

PLATE II.

8 INCH EXPLOSIVE GELATINE SHELL FOR B. L. RIFLE



A A Cast Iron. B Brass.
C Elastic Cushion. D D Paper Case.

Appendix 19—1884.

APPENDIX 20.

REPORT ON THE LYMAN-HASKELL MULTICHARGE GUN.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, D. C., June 14, 1884.

The honorable the SECRETARY OF WAR:

SIR: I have the honor to return herewith letter from the House Committee on Military Affairs, inclosing a memorial from J. R. Haskell asking for an appropriation for the construction of three multicharge guns, and to report:

Attention is invited to the inclosed report of the Ordnance Board, to whom these papers were referred.

I concur with the conclusions of the Board, as expressed in their summary statement of objections to the multicharge-gun system.

The very great weight of the multicharge gun, relatively to its caliber, is a primary objection to the system. The single-charge guns of ordinary type, approximating to it in weight, are of 9 and 10 inches caliber, and possess an absolute piercing power of from one and one-half to two and one-half times that of the multicharge gun, without taking into account the much larger perforations produced by the larger 9 and 10 inch projectiles. The total energy—*smashing effect*—imparted to the latter, which is regarded as the measure of effect against *hard* armor, is from two and one-half to three and one-half times that of the multicharge gun.

It does not appear probable that the weight of this gun can be reduced to anything like that of a single loader of the same caliber. The huge protuberances, in which are formed the loading pockets, keep up the weight of the breech portion; whilst, owing to the condition that "instead of all the pressure being concentrated in the breech it is evenly distributed along the bore," the weight of the front or chase portion must be kept up considerably above what is required with ordinary guns.

If the weight of the 6-inch multicharge gun were reduced to one-half its present weight, it would still be three times as heavy as a modern 6-inch single-charge gun; and yet the power of the latter has nearly equaled that of the multicharge gun, and with a saving of nearly two-thirds the weight of the powder charge. This leads me to refer to a secondary, but not unimportant, objection, namely, the *waste* of the useful effect of the powder charge with the multicharge gun. The charge used with the 6-inch multicharge gun, on which the Ordnance Board and Mr. Haskell have based their comparisons, was 109 pounds, giving to a projectile of 110 pounds a velocity of 1,935 feet for a pressure on the bore of 23,600 pounds. The relative utilization of the charge with the 6-inch single-charge guns has just been mentioned.

To take another instance: the Krupp 8¼-inch single-charge gun, of only *one-half* the weight of the 6-inch multicharge, with a charge of 99 pounds, imparts to its projectile of 310 pounds, and of from three and one-half to four and one-half calibers length, a velocity of 1,780 feet, with the moderate pressure on the bore of 33,600 pounds—15 tons. This gives a piercing power for the 8¼-inch gun of nearly one and three-quarters times, and a smashing effect of nearly two and one-half times, that of the 6-inch multicharge gun, whilst the energy realized per pound of powder is about 69 foot-tons for the Krupp gun, and only 27 foot-tons for the multicharge. The great improvements made with powders within the last two years—as shown from the firing records of European guns—render it very probable that with single-charge guns quite as favorable average results will be obtained, caliber for caliber, as with the multicharge, and without borrowing from the latter any of its objectionable features. Even should the pressure prove to be higher, the single-charge gun can be made much the stronger construction, and therefore is not to be regarded as any the less *safe*.

The objections to the gun as a system of construction and as a practicable arm for the service are fairly stated, it is believed, in the report of the Ordnance Board.

If it should be thought desirable that further trials be made with this system, in order to its more complete development, the existing 6-inch multicharge gun, now at the Proving Ground, Sandy Hook, is being put in a serviceable condition and could be utilized for that purpose.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

Report on the memorial of J. R. Haskell to the House Committee on Military Affairs, referred to the Ordnance Board by the Chief of Ordnance, dated June 4, 1884.

The points urged in the memorial are principally three, which, briefly stated, are:

1. A claim that experiments with a 6-inch Lyman-Haskell multicharge gun weighing about 25 tons have given results far superior to those obtained from similar guns of simple construction, the bases of comparison being the results obtained with a Krupp 5.87-inch gun weighing 3.8 tons, and an Armstrong 6-inch gun weighing 3.9 tons.
2. That if the above claim be admitted, the Government should continue the experiment by appropriating the sum of $250,000 for three 8-inch multicharge guns.
3. That one of these 8-inch guns should be made of Atwood's metal.

The Ordnance Board is directed to hear the memorialist in person, to report on the points made, and to express an opinion as to the advisability of recommending an appropriation.

The Board has heard Mr. Haskell and examined all the accompanying papers and drawings.

The advantages claimed for the multicharge system of gun construction are that a much greater energy, with less pressure per square inch on the bore of a gun and within the limits of safety, can be obtained than with any gun of the same caliber employing only a single charge of powder.

An analysis of the practical results obtained with the 6-inch multicharge at Sandy Hook and of the construction itself are the only guides upon which the Board has to rely in forming its opinion as to whether the advantages claimed have been realized and as to the value of this system of gun construction.

There seems to be no doubt that a higher energy has been obtained with this gun with its successive charges and with moderate and safer pressures than can result from any gun of the same caliber using only one charge.

It seems, however, to the Board that a proper comparison of this system with the single-charge system should be made with guns of like weight, and for this purpose the following analysis is presented, giving the data obtained with this 6-inch gun and with others:

	Caliber.	Weight.	Weight of projectile.	Weight of charge.	Initial velocity.	Pressure per square inch.	Total energy.	Energy per inch of shot's circumference.
	Inches.	*Tons.*	*Pounds.*	*Pounds.*	*Feet.*	*Pounds.*	*Foot-tons.*	*Foot-tons.*
Multicharge ..	6	25	110	109	1, 935	23, 000	2, 885	151. 5
American M. L.	10	18	400	70	1, 400	22, 000	5, 443	173. 25
Italian.........	9. 448	17	330	66	1, 426. 8	32, 000	4, 663. 7	157

These two guns, which give results about the same as the Lyman-Haskell, and weigh much less, are very inferior to the best guns of a similar type made at present, *e. g.:*

	Caliber.	Weight.	Weight of projectile.	Weight of charge.	Initial velocity.	Pressure per square inch.	Total energy.	Energy per inch of shot's circumference.
	Inches.	*Tons.*	*Pounds.*	*Pounds.*	*Feet.*	*Pounds.*	*Foot-tons.*	*Foot-tons.*
Krupp	9	18	299.2	132	1,872	29,537	7,280.5	257.5

Hence, simple guns of much less weight far exceed the results obtained with the multicharge gun so far as it has been experimented with.

If we compare it with a simple gun of the latest type approximating more nearly to it in weight, we have:

	Caliber.	Weight.	Weight of projectile.	Weight of charge.	Initial velocity.	Total energy.	Energy per inch of shot's circumference.
	Inches.	*Tons.*	*Pounds.*	*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*
Whitworth	9.5	20	403	197	1,997	11,158	378.85

In these guns the pressures exceed those in the Lyman-Haskell 6-inch, but do not exceed those generally considered as within safe limits.

Hence, as to the first point, the Board would report that it is fallacious to compare a 6-inch gun weighing 25 tons with 6-inch guns weighing 3.9 tons, and as far as experiments have gone the Lyman-Haskell 6-inch gun is greatly inferior to those simple guns with which it should properly be compared.

As to the second point, it is thought that the remarks made with reference to the 6-inch gun would apply to the proposed steel 8-inch gun, as the latter would weigh about as much as a modern 12-inch single-charge steel gun.

As to the third point the Board would report that it has no sufficient data to decide as to whether Atwood's metal is suitable for guns, and further, that it is not considered judicious to use an untried metal in the construction of large guns.

It is admitted that the 6-inch gun is made of inferior metal, but there is no indication that a diminution of weight or an increase of strength would permit this piece to compare favorably with simple guns of the same weight.

The objections to the system may be summed up as follows: A much longer and more objectionable length of gun for the same caliber than the single-charge gun; the necessity of using different grades of powder for the pockets, thus rendering confusion and accident liable in action; the much greater length of time required to load such a gun; the irregular exterior surface of the gun, making it a difficult problem to make a suitable carriage for it; and finally, the much greater cost of construction from its complicated character than the single-charge gun.

The Board, in this statement, simply presents the facts in the case. An analysis of the record, exhibiting the actual performance of the gun, shows its work, its capacity as a propulsive engine, compared with other guns, by the rules now recognized as standards among military men throughout the world. A reference to this analysis will show the gun's status accordingly.

The Board bases its judgment as to the practicability and efficiency of these guns mainly upon the analysis herewith given, and finds it impossible to express the opinion that it is advisable to recommend an appropriation for their construction.

The Board cannot finish this report without giving its earnest testimony as to its belief in the sincere integrity of Mr. J. R. Haskell, and expressing its admiration for his courage and energy. Believing thoroughly in the principle of his invention, he has, unaided by the Government, wrecked his fortune and impoverished himself and family in his efforts to provide a powerful weapon for the national defense.

He stands high among all who know him, and no higher anywhere than with the members of this Board, who have for years watched his struggles, under adverse circumstances, to perfect his invention.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.

Record of firing with 6" multicharge gun at Sandy Hook,

	No. of fire.	Date.	Powder.					Projectile.			Elevation.
			Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.	Kind.	Weight.		
								For multicharge gun.	*Lbs.*	*oz.*	° '
Barometer, 30.036; thermometer, 72.5; humidity, 40.	1	Sept. 5	Ka12	0	0	0	0	3 calibres long ..	108	8	−50
Barometer, 29.990; thermometer, 71; humidity, 66.	2	Sept. 5	Ka15	0	0	0	0	3 calibres long ..	109	0	−30
Barometer, 30.276; thermometer, 59; humidity, 60.	3	Sept. 6	Ka15	0	0	0	0	3 calibres long ..	108	0	−25
Barometer, 30.223; thermometer, 68; humidity, 50.	4	Sept. 6	Ka15	Kb15	0	0	0	3 calibres long ..	110	0	−35
Barometer, 30.150; thermometer 70; humidity, 47.	5	Sept. 6	Ka15	Kc15	Kc15	0	0	3 calibres long ..	110	0	−35
Barometer, 30.062; thermometer, 59; humidity, 70.	6	Sept. 7	Ka15	Kc20	0	0	0	3 calibres long ..	110	0	−35
Barometer, 30.238; thermometer, 63; humidity, 68.	7	Sept. 18	Ka15	0	0	0	0	*Altered at Hook.* 3 calibres long ..	109	0	−25

N. J., from September 5 to September 20, 1883.

Pressure per square inch of bore.					Inst'l velocity, 103' 3' from muzzle.	Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc.
Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.					
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Feet.*	*Ft.*			
1, 250					1, 063 1, 067 1, 071	0. 27	From rear and right 44°, 26 miles.	Fired into sand butt.	Pocket pressure plugs removed before firing and closed with solid plugs. Block unlocked with some difficulty by removing handle and pinion and hammering lever with handspike. Gas had left considerable traces around obturator and had worked along thread between copper and steel of head, setting out the former about $\frac{1}{32}$ of an inch, the cause to some extent of the difficulty in opening block. To correct this a piece of sheet copper was fastened by three screws to the face of the obturator so as to cover the joint between the steel and the copper.
25, 175					1, 199 1, 202 1, 205	0. 67	From rear and right 44°, 15 miles.		Same difficulty in opening block as before, due apparently to same cause, the gas having passed under the sheet copper and again followed thread between the copper and steel of head. A projecting rim of the sheet copper was then removed so that it could lie flat against face of the obturator.
24, 800					1, 206 1, 208 1, 210	1. 04	From rear and right 44°, 8 miles.		Gun not opened at once, and then only with slightly less difficulty, and gas found still to have insinuated itself under sheet copper and along thread, as before. Before firing again bearing surface of obturator was dressed off. Fragment of gas check thrown at the discharge to vicinity of bell tower, about fifty yards to the right.
23, 500	*18, 000				1, 341 1, 345 1, 349	0. 79	From rear and right 44°, 8 miles.		Gun not opened at once, and then with less difficulty than at any previous round and less traces of gas about obturator. No escape of gas about pocket plugs, which was cleaned off and replaced without alteration.
24, 000	*18, 000	*18, 000			1, 504 1, 506 1, 508	1. 42	From front and left 89°, 10 miles.		Block opened as before, but without removing pinion and with more ease. Very large escape of gas around obturator and around the copper ends of the pocket plugs.
22, 100	25, 850				1, 451 1, 455 1, 459	0. 83	From rear and right 44°, 6 miles.		Block opened as in previous round; gas escape at breech less than at any previous round, but considerable about copper end of pocket plug.
23, 500					1, 206 1, 206 Lost.	0. 42	From front and left 89°, 20 miles.		

* Below.

Record of firing with 6″ multicharge gun at Sandy Hook, N. J.,

	No. of fire.	Date.	Powder.					Projectile.		Elevation.
			Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.	Kind.	Weight.	
								Altered at Hook.	*Lbs. oz.*	° ′
Barometer, 30.230; thermometer, 68; humidity, 61.	8	Sept. 18	Ka14	0	0	0	0	3 calibers long ..	109 0	−30
	9	Sept. 18	Ka14	Kc18	Kd15	0	0	3 calibers long ..	108 0	−35
Barometer, 30.326; thermometer, 59; humidity, 75.	10	Sept. 19	Ka14	Kc18	Kd18	0	0	3 calibers long ..	110 0	−25
	11	Sept. 19	Ka14	Kc18	Kd17	0	0	3 calibers long ..	109 0	−25
	12	Sept. 19	Ka14	Kc18	Kd17	Ke17	0	3 calibers long ..	106 0	−30
Barometer, 30.075; thermometer, 75; humidity, 48.	13	Sept. 20	Ka14	Kc18	Kd17	Ke17	Kg17	3 calibers long ..	109 0	−35

from September 5 *to September* 20, 1883—Continued.

Pressure per square inch of bore.					Inst'l velocity, 103' 3" from muzzle.	Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.					
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Feet.*	*Ft.*			
20,900	......	......	......	......	1,163 1,166 1,169	0.35	From front and left 43°, 18 miles.	Fired into sand butt.	Block unlocked with more or less difficulty, and bearing surface of obturator eased off after each round from 7 to 11 inclusive.
20,600	20,700	*18,000	......	......	1,514 1,514 1,514	1.46			
20,600	......	22,200	......	......	1,553 1,558 1,563	1.83	From rear and left 43°, 22 miles.		
20,900	20,400	20,200	......	......	*18,000 1,552 1,554 1,562	1.79			
20,400	20,700	19,600	20,200	......	†12,000 1,673 1,673 Lost	2.67			When washed out pocket which had not yet been used choked at the mouth with powder scale.
20,200	......	20,400	19,400	21,200	†13,000 1,735 1,735 1,735	4.20	From front and left 89°, 6 miles.		Spring in pressure plug holding disk in third pocket broken and the one in second pocket injured. After this round firing suspended for the purpose of making repairs and alterations to the obturator and to the pocket plugs.

* Below. † Muzzle.

Record of firing with 6-inch multicharge gun at Sandy

	No. of fire.	Date.	Powder.					Projectile.		Elevation.
			Breech.	1 pocket.	2 pocket.	3 pocket.	4 pocket.	Kind.	Weight.	
		1883.							*Lbs.*	° ′
Barometer, 30.581; thermometer, 59; humidity, 52; 20 miles an hour.	14	Oct. 18	Ka. 14	Kc. 18	Kd. 17	Ke. 17	Kg. 17	3 calibers long	110	0 35
	15	Oct. 18	Ka. 14	Kc. 18	Kc. 18	Kd. 18	Ke. 18	3 calibers long	110	0 35
Barometer, 30.398; thermometer, 59; humidity, 75; 12 miles an hour.	16	Oct. 19	Ka. 14	Kc. 18	Kc. 18	Kd. 18	Ke. 18	3 calibers long	110	0 35
	17	Oct. 19	Ka. 15	Kc. 20	Kc. 20	Kd. 20	Ke. 20	2 calibers long	72	0 35
Barometer, 30.275; thermometer, 64; humidity, 78; 18 miles an hour.	18	Oct. 19	Ka. 16	Kc. 20	Kd. 20	Ke. 20	Kg. 20	2 calibers long	71	0 35
	19	Oct. 19	Ka. 15	Kd. 18	Ke. 18	Kg. 18	Kf. 18	3 calibers long	111	0 35
Barometer, 30.311; thermometer, 49; humidity, 100; 30 miles an hour.	20	Oct. 23	Km. 15	Kca. 18	Kd. 18	Ke. 18	Kg. 18	3 calibers long	110	0 35
Barometer, 30.114; thermometer, 47; humidity, 77; 21 miles an hour.	21	Oct. 24	Km. 15	Kb. 20	Kca. 20	Kd. 20	Ke. 20	3 calibers long	112	0 35
	22	Oct. 24	Km. 15	Kb. 20	Kca. 20	Kd. 20	Ke. 20	3 calibers long	111	0 35
	23	Oct. 24	Km. 15	Kb. 20	Kca. 20	Kca. 22	Kca. 22	3 calibers long	109	0 35
Barometer, 30.098; thermometer, 49; humidity, 71; 28 miles an hour.	24	Oct. 24	Km. 15	Kb. 20	Kb. 22	Kca. 22	Kca. 22	3 calibers long	110	3 0
	25	Oct. 24	Km. 15	Kb. 20	Kb. 22	Kca. 22	Kca. 22	3 calibers long	110	3 0
	26	Oct. 24	Km. 13	Kb 17	Kb. 17	Kca. 17	Kca. 17	4 calibers long	151	3 0

Hook, N. J., from October 18 *to October* 26, 1883.

Pressure per square inch of bore.						Instrumental velocity.				
Breech.	1 pocket.	2 pocket.	3 pocket.	4 pocket.	Muzzle.	103′ 3″ from muzzle.	Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Lbs.	*Lbs*	*Lbs*	*Lbs.*	*Lbs*	*Lbs*	*Feet.*	*Feet.*			
20,000	20,100	19,600	Less inch. 18,000	19,000	11,500	1,759 1,761 1,763	4.50	From front and right, 2°.	Fired into sand butt. Traces of gas were found, varying in amount, after each round, over the outer surfaces of plugs, and of obturator, which, though at times slight, at the 23d round extended over the whole length of the breech-block to the lower handle. The breech mechanism worked fairly well and was generally opened by hand.	Before firing round 14, new steel plugs were fitted to pockets, and a copper bushing 1 inch long inserted in front of vent in consequence of a detected flaw in the steel.
18,800	19,800	19,800	Lost.	20,200	23,000	1,730 1,732 1,734	4.67			After round 15, the copper stem of plug for front pocket was broken off while being withdrawn and was replaced by a steel stem.
19,000	18,800	19,600	20,200	18,800	14,000	1,756 1,757 1,758	4.83			
18,800	21,200	22,400	21,800	24,000	......	2,048 2,051 2,054	4.62			At round 17, new and thicker copper disc attached to face of obturator to cover joint, a thicker one being substituted at round 20.
20,400	20,200	21,000	22,800	27,700	......	2,097 2,101 2,105	4.83			The seats for copper plugs for all the pockets wearing away, the bearings of the plugs were impaired, and in the case of the 4th pocket the plug was somewhat set out. These seats had, therefore, to be reamed out after the 26th round.
20,800	20,200	21,000	22,600	30,000	......	1,831 1,832 1,833	5.17			
20,200	19,000	20,200	19,000	20,500	......	1,789 1,791 1,793	5.08	From front and left, 8°.		
23,400	20,400	20,500	22,000	22,700	......	1,812 1,813 1,814	5.08	From rear and left, 2°.		
20,800	20,700	20,200	25,000	24,800	......	1,778 1,780 1,782	5.08			
20,600	20,400	20,400	24,600	26,200	......	1,805 1,808 1,811	5.17			
						116′ from muzzle.				
21,800	20,200	24,000	21,600	25,100	......	1,813 1,814 1,815	6.04			
21,300	20,600	22,800	21,800	25,000	......	1,801 1,802 1,802	5.92			
19,000	19,800	19,000	19,800	18,000	......	1,449 1,449 1,449	4.71			

The following is the record of the powders received from E. I. Du Pont de Nemours & Co., for use in this gun:

	Sp. gr.	*Gr.*	
Ka	....1.785 sp. gr.	67	Hex.
Kb	...1.750 sp. gr.	123	Sphero-hex.
Kc	....1.744 sp. gr.	1.290	
Kd	...1.746 sp. gr.	7.176	
Ke	....1.746 sp. gr.		
Kf	....1.375 initial velocity		musket.
Kg	...1.300 initial velocity		musket.
Km	...1.790 sp. gr.	40	Hex.
Kaa	..Like Ka.		
Kca	..Like Kc ...		Through, 0.″5. On, 0.″5.
Kda	..Like Kd ...		Through, 0.″3. On, 0.″15.
Kea	...Like Ke ...		Through, 0.″015 On, 0.″1.
Kfa	...Like Kf.		
Kga	..Like Kg.		
Kl	....Rifle iv., 1418.		

Record of firing with 6-inch multicharge gun at Sandy

	No. of fire.	Date.	Powder.					Projectile.		Elevation.	
			Breech.	1 pocket.	2 pocket.	3 pocket.	4 pocket.	Kind.	Weight.		
		1883.							*Lbs*	°	'
Barometer, 30.059; thermometer, 51; humidity, 59; 1 mile an hour.	27	Oct. 25	Km. 14	Kd. 18	Kb. 18	Kca. 18	Kca. 18	4 calibers long	155	1	0
	28	Oct. 25	Km. 16	Kb. 22	Kca. 20	Kd. 20	Ke. 20	3 calibers long	110	1	0
Barometer, 29.994; thermometer, 53; humidity, 80; 8 miles an hour.	29	Oct. 26	Km. 14	Ka. 20	Ka. 20	Kb. 20	Kca. 20	4 calibers long	155	1	0
	30	Oct. 26	Km. 17	Ka. 23	Kb. 23	Kca. 23	Kd. 23	3 calibers long	110	1	0
	31	Oct. 26	Km. 17	Km. 23	Ka. 23	Ka. 23	Kca. 23	3 calibers long	111	1	0

Hook, N. J., from October 18 to October 26, 1883—Continued.

Pressure per square inch of bore.						Instrumental velocity.	Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Breech.	1 pocket.	2 pocket.	3 pocket.	4 pocket.	Muzzle.	116′ from muzzle.				
Lbs.	*Lbs*	*Lbs*	*Lbs*	*Lbs*	*Lbs*	*Feet.*	*Feet.*			
21,600	19,600	20,100	20,400	19,000	......	1,485 1,486 1,486	5.42	From rear and left, 2°.	Fired into sand butt. Traces of gas were found, varying in amount, after each round, over the outer surfaces of plugs, and of obturator, which, though at times slight, at the 23d round extended over the whole length of the breech-block to the lower handle. The breech mechanism worked fairly well and was generally opened by hand.	
23,200	24,000	19,600	22,000	21,400	......	1,863 1,864 1,865	5.50			
19,600	19,600	20,400	21,000	20,700	......	1,554 1,558 1,562	6.50	From front and left, 89°.		
23,600	26,600	21,400	25,500	29,000	......	1,923 1,924 1,925	7.50			
21,400	22,900	21,600	26,000	27,500	......	1,760 1,760 (?)	6.67			Firing ceased in order to provide new steel obturator and loading plugs and to add steel bushings for seats for the latter.

Record of firing with 6-inch multicharge gun at

	Number of fire.	Date.	Powder.					Projectile.			Pressure per square inch of bore.				
			Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.	Kind.	Weight.	Elevation.	Breech.	1st pocket.	2d pocket.	3d pocket.	4th pocket.
									Lbs	° ′	*Lbs*	*Lbs*	*Lbs*	*Lbs*	*Lbs*
Barometer, 30.041; thermometer, 65; humidity, 78.	....	....	K. M.	K. M.	K. A.	K. A.	K. C. A.								
	32	Nov. 22	17	23	23	23	23	3 calibers long	111	30	28, 200	27, 400	21, 600	28, 300	18, 000
	....	....	K. M.	K. A.	K. R.	K. B. A.	K. A.								
	33	Nov. 22	18	24	24	24	24	2 calibers long	72	30	21, 400	29, 300	21, 200	29, 700	20, 200

Dec. 13, 1884.

Sandy Hook, N. J., on November 22, 1883.

Instrumental velocity 102′ 3″ from muzzle.	Recoil.	Wind, strength, and direction.	Pressure per square inch of bore.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			1st loading-hole.	2d loading-hole.	3d loading-hole.	4th loading-hole.	
Feet.	*Feet.*		*Lbs*	*Lbs*	*Lbs*	*Lbs*	
1, 822	......	From right and front 40°; 8 miles an hour.					Fired into sand butt. The following lots of powder have been received for this gun since those last reported: *Spec. gravity.* — *Gr.* Hexagonal K. A. B. 1.785 67 Sphero-hex. K. B. A. 1. 750 123 K. C. B. 1. 744 Through 0.5 on 0.3 Hexagonal K. M. A. 1. 790 40 K. P. 1. 770 Through 0.5 on 0.3 K. Q. 1. 795 Through 0.6 on 0.4 Sphero-hex. K. R. 1. 790 123 Do. K. S. 1. 730 123 K. D. B. 1. 746 Through 0.3 on 0.15 K. E. B. 1. 746 Through 0.15 on 0.1 Before firing round 32 a new steel obturator made of a single piece was substituted for that previously used, and new steel plugs for loading-holes were supplied with pressure plugs, similar to those at the pockets. The plugs for pockets and loading-holes were perfectly clean when withdrawn after firing. After rounds 32 and 33 gun opened by hand easily. Escape of gas on lower side of obturator during both rounds. After round 33 a crack was found in steel tube commencing at the muzzle and extending to within 13 inches of the 4th or forward pocket. (5)Impressions of bore accompanying this report.
1, 824	4. 50		21, 800	18, 000	18, 000	18, 800	
1, 826	......						
2, 132	......						
2, 135	3. 75		22, 700	18, 800	18, 000	20, 200	
2, 138	......						

APPENDIX 21.

TRIAL OF AN 8-INCH MUZZLE-LOADING RIFLE, LINED WITH A STEEL TUBE CONVERTED FROM A 10-INCH SMOOTH-BORE RODMAN GUN BY THE BOARD FOR TESTING RIFLED CANNON, APPOINTED UNDER ACT OF JULY 5, 1884.

The trial of this gun by the Ordnance Board, U. S. A., was directed in Ordnance Office letter dated May 17, 1884. The gun was transferred by that Board to the "Board for Testing Rifled Cannon, &c.," by first indorsement of July 31, 1884, upon the same letter. The Ordnance Board had fired the piece 259 rounds previous to the transfer.

This gun was converted from a 10-inch Rodman smooth-bore (No. 113 W. P. F.) by lining it with a tube made from Midvale open-hearth steel. The breech-cup and muzzle-collar are both of Midvale steel. The collar was not annealed.

THE TUBE.

This was made from a solid forging 126.75 inches long, and 14.5 inches in diameter. The physical properties[*] of the metal are as follows:

Tenacity (mean of 3 tangential specimens) .... pounds per square inch..	79.400
Elongation after rupture .... per cent..	22.6
Contraction of area .... do	30.2
Elastic limit .... pounds per square inch..	37.000

THE BREECH-CUP.

This was made from a solid steel cylinder 8.7 inches long and 8.65 in diameter.[*]

THE MUZZLE-COLLAR.

This was made from a hollow cylinder 7.1 inches in length, 13.75 inches exterior, and 11.22 inches interior diameter.[*]

The breech-cup and muzzle-collar were taken from the same ingot. The former was annealed.

The physical properties[*] of this ingot were as follows:

	Before annealing.	After annealing.
Tenacity .... pounds per square inch..	77.570	73.500
Elongation after rupture .... per cent..	13.5	27.5
Contraction of area .... do....	13.2	38

The tube was inserted without shrinkage, a play of 0.005 inch being allowed between the exterior diameter of the tube and the interior diameter of the casing. The tube is secured to the casing by the muzzle-collar and securing-pin.

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[*] Information furnished by inspector of ordnance, Boston, Mass.

RIFLING.[*]

Number of grooves		24
Width of grooves	inch..	0.6982
Depth of grooves	do..	0.065
Width of lands	do..	0.349
Radius of fillet-bottom of lands	do..	0.075
Lands rounded with radius of	do..	0.01
Twist uniform, one turn in	feet..	30

Vent copper bushed.

A gas-escape is bored through the casing at the rear end of the tube.

PRINCIPAL DIMENSIONS.[*]

		Prescribed.	Actual.
Total length of tube	inches.	120	120.07
Thickness at bottom of steel cup	do..	2.75	2.75
Diameter finished tube	do..	13	12.994
Diameter bore of casing	do..	13.005	12.999
Corresponding play	do..	0.005	0.005
Diameter tube over neck	do..	11.5	11.489
Interior diameter of muzzle-collar	do..	11.505	11.493
Corresponding play	do.	0.005	0.004
Length of bore	do.	117.25	117.23
Length of rifled portion of bore	do..	101.75	101.85
Diameter of bore across lands	do..	8	8.014
Distance of center of gravity in front of axis of trunnions	do..		[†]1.87
Weight of gun	pounds.		15,960
Counter preponderance	do..		537

[*] Information furnished by inspector of ordnance, U. S. A., Boston, Mass.

[†] Ordnance Office letter, May 17, 1884.

EXPERIMENTS.

These were conducted at the Ordnance Proving Grounds at Sandy Hook, N. J.

PROJECTILES.

The Butler 8-inch projectiles were used throughout the tests, since the 8-inch wrought-iron-lined guns heretofore made had been proved and fired with these projectiles.

POWDERS.

Du Pont's hexagonal powders E. V. L., E. V. H., E. V. K., E. V. M., E. V. N., density 1.750, granulation 72; Du Pont's sphero-hexagonal L. C., density 1.815, granulation 123, and K. H. C., density 1.775, granulation 123, were used for the firings.

RESULTS OF FIRING.

The details of the firing will be found in the firing record and table of enlargements appended and forming part of this report. The following Table I shows the pressures and velocities obtained with the different charges and kinds of powder, together with the different weights of projectiles.

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[*] Information furnished by the inspector of ordnance, U. S. A., Boston, Mass.

I.—*Table showing pressures and velocities obtained with 8-inch muzzle-loading rifle No. 1, steel tube, muzzle insertion.*

Number of fire.	Number of rounds.	Powder.		Butler projectile.	Pressure per square inch of bore (Rodman).	Instrumental velocity 110′ from muzzle.	Remarks.
		Kind.	Weight.	Weight.			
			Pounds.	*Pounds*	*Pounds.*	*Feet.*	
1 and 3	2	Du Pont's hexagonal powder; density, 1.75; granulation, 72. E. V. L.	25	180	29, 250	1, 257	Mean pressure and velocity.
2 and 4	2	E. V. H.	25	180	36, 250	1, 307	Mean pressure and velocity. p. v. max. 37, 500 1, 313 min. 35, 000 1, 300
5	1	E. V. L.	30	181	37, 000	1, 335	
6	1	E. V. K.	30	181	40, 500	1, 362	
7	1	E. V. M.	30	181	27, 000	1, 280	
8 and 9	2	E. V. M.	35	181	29, 875	1, 360	
10 to 14	5	E. V. M.	35	182	29, 400	1, 370	Mean pressure and velocity. p. v. max. 30, 750 1, 382 min. 28, 500 1, 355
15 to 19	5	E. V. N.	35	182	30, 000	1, 365	Mean pressure and velocity. p. v. max 30, 750 1, 369 min. 27, 500 1, 355
29	1	E. V. M.	35	183	29, 000	1, 375	
39	1	E. V. M.	35	184	26, 000	1, 354	
49	1	E. V. M.	35	183	30, 250	1, 364	
59	1	E. V. M.	35	183	34, 000	1, 386	
69	1	E. V. M.	35	181	29, 250	1, 366	
79	1	E. V. H.	35	183	30, 750	1, 362	
89	1	E. V. N.	35	182	31, 250	1, 378	
99	1	E. V. N.	35	184	29, 750	1, 363	
109	1	E. V. N.	35	183	29, 500	1, 354	
119	1	E. V. N.	35	180	31, 500	1, 370	
129	1	E. V. N.	35	182	32, 750	1, 388	
130	1	E. V. M.	35	181	25, 750	1, 309	
131	1	E. V. M.	40	181	29, 250	1, 356	
132 and 134	2	Du Pont's hexagonal E. V. M.; density, 1.75; granulation, 72.	42	181	30, 000	1, 395	Mean pressure and velocity.
133	1		42	181	23, 500	1, 397	Pressure abnormal; disk hard; probably 30,000 pounds.
135 and 136	2		45	181	33, 625	1, 448	Mean pressure and velocity.
137 to 139	3		43	181	30, 417	1, 391	Mean pressure and velocity. p. v. max. 32, 000 1, 398 min. 29, 500 1, 382
140	1	L. C.	35	181	18, 100	Lost.	Du Pont's sphero-hexagonal powder L. C.; density, 1.815; granulation, 123.
141 and 142	2	L. C.	40	181	21, 750	1, 252	Mean pressure and velocity. p. v. max. 21, 900 1, 255 min. 21, 600 1, 248
143	1	Du Pont's hexagonal E. V. M.; density, 1.75; granulation, 72.	42	181	29, 400	1, 385	
144	1		43	181	30, 600	1, 389	
145	1		45	181	30, 900	1, 427	
						108′ 4″	
160	1		45	183	26, 400	1, 352	
180	1		45	181	27, 100	1, 350	
200	1		45	183	28, 400	1, 376	
220	1		45	182	32, 800	1, 429	
240	1		45	180	27, 600	1, 388	
						109′	
260 to 269	10	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 123.	35	180	31, 130	1, 380. 2	Mean pressure and velocity. p. v. max. 34, 400 1, 408 min. 28, 500 1, 354
281	1		35	182	30, 350	1, 370	
301	1		35	*178	30, 250	1, 369	
321	1		35	182	31, 950	1, 385	
341	1		35	181	29, 100	1, 365	
361	1		35	183	30, 750	1, 376	
381	1		35	181	26, 650	1, 325	
401	1		35	180	29, 100	1, 370	
421	1		35	182	30, 550	1, 383	
441	1		35	184	31, 000	1, 399	
461	1		35	180	30, 150	1, 392	

* Old projectile.

The kind and charges of powder, number of rounds fired with each, the maximum, minimum, and mean pressures and velocities, are given in Table II.

The enlargements of bore after firing 500 rounds are given in Table III.

II.—*Condensed table showing kinds and charges of powder, number of rounds fired with each, maximum, minimum, and mean pressures and velocities.*

RODMAN GAUGE.

Number of rounds.	Powder.		Pressure per square inch of bore.			Initial velocity 110 feet from muzzle.			Remarks.
	Kind.	Weight.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Feet.*	*Feet.*	*Feet.*	
2	E. V. L.	25	29, 500	29, 000	29, 250	1, 266	1, 247	1, 257	Hexagonal.
2	E. V. H.	25	37, 500	35, 000	36, 250	1, 313	1, 300	1, 307	Do.
1	E. V. L.	30	....	....	37, 000	....	....	1, 335	Do.
1	E. V. K.	30	....	....	40, 500	....	....	1, 362	Do.
1	E. V. M.	30	....	....	27, 000	....	....	1, 286	Do.
11	E. V. N.	35	32, 750	27, 500	30, 500	1, 388	1, 354	1, 367	Do.
13	E. V. M.	35	34, 000	25, 500	29, 308	1, 386	1, 309	1, 365	Do.
1	E. V. M.	40	....	....	29, 250	....	....	1, 356	Do.
1	E. V. M.	42	....	....	*23, 500	....	....	1, 397	Do.
2	E. V. M.	42	30, 250	29, 750	30, 000	1, 396	1, 393	1, 395	Do.
3	E. V. M.	43	32, 000	29, 500	30, 417	1, 398	1, 382	1, 391	Do.
2	E. V. M.	45	33, 750	33, 500	33, 625	1, 454	1, 441	1, 448	Do.

*Abnormal disk hard, probably 30,000.

CRUSHER GAUGE.

1	L. C.	35	....	....	18, 100+	....	....	Lost.	Sphero-hexagonal.
2	L. C.	40	21, 900	21, 600	21, 750	1, 255	1, 248	1, 252	Do.
20	K. H. C.	35	34, 400	28, 500	30, 558	1, 408	1, 325	1, 378	Do.
1	E. V. M.	42	....	....	29, 400	....	....	1, 385	Hexagonal.
1	E. V. M.	43	....	....	30, 300	....	....	1, 389	Do.
6	E. V. M.	45	32, 800	26, 400	28, 867	1, 429	1, 350	1, 387	Do.

III.—*Table showing enlargement of bore after 500 rounds, as shown by Star gauge.*

Inches from muzzle.	Original diameter.	After 500 rounds.	Enlargement.	Remarks.	Inches from muzzle.	Original diameter.	After 500 rounds.	Enlargement.	Remarks.
	Inches.	*Inches.*	*Inches.*			*Inches.*	*Inches.*	*Inches.*	
101	8. 022	8. 050	+0. 028		82	8. 021	8. 046	+0. 025	
100	8. 022	8. 049	. 027		81	8. 021	8. 044	. 023	
99	8. 022	8. 049	. 027		80	8. 021	8. 044	. 023	37. 25 inches.
98	8. 022	8. 049	. 027		78	8. 021	8. 038	. 017	
97	8. 022	8. 048	. 026		76	8. 021	8. 036	. 015	
96	8. 022	8. 049	. 027		74	8. 021	8. 034	. 013	
95	8. 022	8. 049	. 027		72	8. 021	8. 030	. 009	
94	8. 022	8. 050	. 028		70	8. 021	8. 028	. 007	
93	8. 022	8. 053	. 031	Maximum about 26 inches from bottom of bore.	68	8. 021	8. 027	. 006	
92	8. 022	8. 054	. 032		66	8. 020	8. 025	. 005	
91	8. 022	8. 054	. 032		64	8. 020	8. 024	. 004	
90	8. 022	8. 050	. 028		62	8. 020	8. 023	. 003	
89	8. 022	8. 051	. 029		60	8. 019	8. 023	. 004	
88	8. 021	8. 050	. 029		58	8. 019	8. 023	. 004	
87	8. 021	8. 050	. 029		56	8. 018	8. 025	. 007	
86	8. 021	8. 050	. 029		54	8. 019	8. 024	. 005	
85	8. 021	8. 048	. 027		52	8. 019	8. 023	. 004	
84	8. 021	8. 047	. 026		50	8. 019	8. 023	. 004	
83	8. 021	8. 047	. 026		48	8. 019	8. 021	. 002	
					46	8. 018	8. 021	. 003	

III.—*Table showing enlargement of bore after* 500 *rounds, &c.*—Continued.

Inches from muzzle.	Original diameter.	After 500 rounds.	Enlargement.	Remarks.
	Inches.	*Inches.*	*Inches.*	
44	8.018	8.020	+0.002	
42	8.018	8.020	.002	
40	8.018	8.019	.001	
38	8.017	8.019	.002	
36	8.017	8.018	.001	
34	8.016	8.018	.002	
32	8.016	8.018	.002	
30	8.016	8.017	.001	
28	8.016	8.017	.001	
26	8.016	8.017	.001	
24	8.016	8.017	.001	
22	8.015	8.017	.002	
20	8.018	8.016	− .002	
18	8.015	8.016	+ .001	
16	8.011	8.016	.005	
14	8.012	8.015	.003	
12	8.012	8.015	.003	
10	8.013	8.014	.001	
8	8.013	8.014	.001	
6	8.013	8.014	.001	
4	8.013	8.014	.001	
2	8.013	8.014	.001	
1	8.012	8.013	.001	

REMARKS.

Using the Rodman gauge for indicating pressures the E. V. L. powder gave moderate pressures but low velocities; the E. V. H. powder gave high pressures and rather low velocities with 25-pound charges.

With 30-pound charges E. V. L. and E. V. K. gave high pressures, while E. V. M. gave moderate pressures and low velocity.

With 35-pound charges E. V. N. and E. V. M. gave pressures between 25,500 pounds and 34,000 pounds, and velocities averaging about 1,365 feet.

With 40 pounds E. V. M. showed no advantage over 35-pound charge, judging from a single round.

Forty-two pounds E. V. M. gave 30,000 pounds pressure, and a velocity of 1,395 feet; 43 pounds showed a little higher pressure and a less velocity; and 45 pounds exceeded the desired limit of 32,000 pounds, giving over 33,000 pounds pressure, but showed an increase of velocity. Taking the pressures with the Crusher gauge the L. C. sphero-hexagonal gave very low pressures and velocities, while K. H. C. sphero-hexagonal with 35-pound charges gave a mean velocity of 1,378 feet, with an average pressure of 30,558 pounds per square inch, comparing favorably with 45-pound charges of E. V. M., which gave an average pressure of 28,867 pounds.

Thus, 35 pounds of K. H. C. sphero-hexagonal has about the same ballistic power as 45 pounds of E. V. M., giving about the same velocities, but with slightly increased pressures.

At the end of the 320th round, the copper vent-bushing was removed and a new one inserted.

The gun was still serviceable after firing 500 rounds.

ENLARGEMENTS OF BORE.

In order to compare the enlargements of this steel-tubed gun with those of the same caliber lined with coiled wrought-iron tubes, the data of the following muzzle-loading guns all lined with coiled wrought-iron tubes were available,* viz:

8-inch rifle No. 1 (experimental) muzzle insertion.

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* Information in regard to these guns was furnished by the records of the Ordnance Board, U. S. A.

8-inch rifle No. 5 (experimental) muzzle insertion.

8-inch rifle No. 1, breech insertion.

The following Table IV shows the zones of maximum enlargements for each of the four guns. The records are taken from the Star-gaugings as near 500 rounds as was possible. It must be remembered that these enlargements are affected by the greater or less *play* between the casing and tube. The Board has not the data in regard to the play at band, except in the case of the gun lined with the Midvale steel tube, which was 0.005 inch, and which is, at least, as low a limit as can be used in manufacture. This table of comparisons shows that the maximum enlargements of the steel tube are less and more uniform than in either of the two wrought-iron tubes, muzzle insertion, and, though exceeding those of the breech-insertion tube, they occur more uniformly:

IV.—*Comparative table of maximum enlargements in bores of 8-inch converted rifles.*

Inches from muzzle.	8-inch rifle No. 1 (experimental), wrought-iron tube, M. I., after 513 rounds.	8-inch rifle No. 5 (experimental), wrought-iron tube, M. I., after 509 rounds.	8-inch rifle No. 1, wrought-iron tube, B. I., after 510 rounds.	8-inch rifle No. 1, Midvale steel tube, M. I., after 500 rounds.
	Inches.	*Inches.*	*Inches.*	*Inches.*
96	0.037	0.022	0.019	0.027
95	.040*	.024	.020	.027
94	.036	.024	.024*	.028
93	.035	.030*	.023	.031
92	.037	.029	.024*	.032*
91	.039*	.028	.024*	.032*
90	.030	.027	.023	.028
89	.036	.043	.023	.029
88	.030	.048*	.022	.029
87	.028	.036	.020	.029
86	.024	.025	.018	.029
85	.021	.018	.018	.027

* Maximum enlargements.

OPINION.

This gun has on several occasions been fired at the rate of from 20 to 30 rounds an hour. On one day, August 14, as shown by the accompanying firing records, 80 rounds were fired, in two series of 40 rounds each, at the rate of 20 rounds an hour. The Board is, therefore, of the opinion that this gun has endured "such rapid firing as a like gun would be likely to be subjected to in actual battle," and that it compares favorably with 8-inch lined guns heretofore made. Therefore, the Board considers its test satisfactory.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

I concur in the above report and opinion of the Board in every respect except that which relates to the comparison of this gun with 8-inch lined guns heretofore made. This tube has done well, but such a comparison is not, in my opinion, called for by the law, or germane to the intent of this inquiry.

GEO. W. McKEE,
Major of Ordnance.

Table of enlargements of 8*-inch muzzle-loading rifle, No.* 1, *M. I. (steel tube).*

Inches from muzzle.	Original play of tube.	Original diameter of bore.	Enlargements, including "setting up" of tube, after—															
			4 rounds—cold.	9 rounds—cold.	19 rounds—cold.	29 rounds—cold.	39 rounds—cold.	49 rounds—cold.	59 rounds—cold.	69 rounds—warm.	79 rounds—warm.	89 rounds—warm.	99 rounds—cold.	109 rounds—cold.	119 rounds—cold.	129 rounds—cold.	139 rounds—cold.	159 rounds—cold.
101	0.005	8.022	0.008	0.012	0.014	0.017	0.018	0.015	0.018	0.019	0.019	0.021	0.021	0.020	0.018	0.022	0.020	0.022
100	.0045	.022	.008	.012	.013	.017	.017	.015	.018	.019	.019	.020	.020	.020	.018	.022	.020	.022
99	.0045	.022	.007	.012	.013	.017	.017	.014	.017	.018	.018	.020	.020	.019	.018	.022	.018	.022
98	.0045	.022	.007	.011	.012	.016	.017	.014	.017	.018	.017	.019	.019	.019	.017	.021	.018	.022
97	.0045	.022	.006	.011	.012	.016	.017	.013	.017	.018	.016	.019	.018	.018	.017	.021	.018	.022
96	.004	.022	.005	.009	.012	.016	.015	.013	.016	.017	.015	.018	.017	.018	.016	.020	.019	.022
95	.0045	.022	.003	.008	.011	.013	.014	.012	.015	.016	.014	.017	.016	.018	.015	.019	.018	.021
94	.0045	.022	.003	.007	.009	.011	.012	.012	.014	.015	.013	.017	.016	.017	.014	.018	.017	.020
93	.004	.022	.002	.007	.008	.009	.011	.011	.013	.014	.013	.016	.016	.017	.013	.017	.017	.020
92	.004	.022	.001	.005	.008	.009	.011	.010	.011	.013	.010	.015	.015	.015	.013	.017	.015	.020
91	.0037	.022	.000	.004	.008	.008	.009	.008	.010	.012	.009	.013	.014	.014	.013	.015	.015	.018
90	.0042	.022	.000	.003	.005	.008	.008	.006	.008	.008	.010	.011	.012	.011	.010	.013	.013	.018
89	.004	.022	—.001	.002	.004	.007	.008	.005	.008	.008	.008	.009	.012	.009	.009	.013	.013	.017
88	.004	.021	.000	.002	.004	.008	.009	.006	.009	.009	.007	.010	.010	.010	.009	.012	.013	.018
87	.004	.021	.000	.002	.004	.005	.005	.004	.009	.006	.006	.009	.009	.009	.008	.009	.010	.017
86	.0042	.021	.000	.002	.004	.005	.004	.003	.004	.005	.004	.007	.006	.008	.007	.007	.010	.016
85	.0045	.021	.000	.003	.003	.005	.005	.003	.004	.005	.005	.007	.006	.007	.005	.007	.009	.015
84	.0045	.021	—.001	.003	.003	.004	.004	.002	.004	.004	.005	.005	.007	.006	.004	.006	.008	.014
83	.0047	.021	.000	.002	.002	.04	.004	.002	.004	.005	.007	.006	.007	.006	.004	.006	.008	.015
82	.0047	.021	.000	.001	.002	.004	.004	.002	.004	.004	.003	.006	.006	.006	.004	.007	.008	.014
81	.0047	.021	.000	.000	.002	.003	.004	.003	.004	.004	.003	.006	.004	.006	.003	.007	.008	.013
80	.0047	.021	—.001	—.001	.001	.003	.008	.003	.005	.004	.003	.007	.004	.006	.004	.006	.007	.012
78	.0047	.021	—.001	—.001	.000	.003	.005	.000	.004	.003	.003	.004	.004	.004	.003	.004	.005	.011
76	.005	.021	—.001	—.001	—.001	.002	.003	.000	.003	.003	.002	.004	.003	.004	.002	.004	.005	.009
74	.005	.021	—.002	—.001	—.001	.002	.003	.000	.003	.003	.000	.005	.003	.003	.001	.003	.003	.008
72	.0047	.021	—.002	—.001	—.001	.001	.002	—.001	.003	.002	.000	.005	.001	.002	.000	.003	.002	.006
70	.005	.021	—.002	—.001	—.001	.000	.002	—.002	.001	.002	.000	.001	.001	.001	—.001	.002	.001	.004
68	.005	.021	—.002	—.002	—.002	.000	.002	—.002	.000	.001	.000	.001	.001	.001	—.001	.002	.000	.003
66	.0047	.020	—.001	—.001	—.001	.001	.001	—.001	.001	.001	.001	.002	.001	.001	—.001	.002	.000	.003
64	.0045	.020	—.001	—.001	—.001	.001	.001	—.001	.001	.001	.002	.001	.001	.000	—.001	.002	.000	.002
62	.0045	.020	—.001	—.001	—.001	.001	.002	—.002	.001	.001	.003	.002	.001	.000	—.001	.001	—.001	.002
60	.0045	.019	—.001	.000	.000	.003	.003	.000	.002	.003	.004	.004	.003	.002	.000	.005	.000	.002
58	.0042	.019	—.001	.000	.000	.004	.004	.000	.003	.002	.004	.004	.003	.002	.000	.003	.000	.002
56	.0047	.018	.000	.000	.001	.003	.005	.001	.005	.003	.004	.005	.005	.003	.001	.004	.001	.006

54	.0047	.019	—.001	—.001	—.001	.000	.004	—.001	.005	.001	.001	.004	.004	.001	.000	.002	—.001	.004
52	.0047	.019	—.001	—.001	—.001	.000	.002	—.001	.002	.001	.001	.002	.002	.001	.000	.001	—.001	.003
50	.0047	.019	—.002	—.001	—.001	.000	.001	—.001	.001	.000	.001	.001	.001	.000	—.002	.001	—.002	.003
48	.005	.019	—.002	—.002	—.001	.000	.001	—.001	.002	.000	.001	.001	.001	.000	—.001	.000	—.002	.001
46	.005	.018	—.001	—.001	—.001	.001	.002	—.001	.001	.000	.002	.002	.001	.001	.000	.001	—.001	.001
44	.005	.018	—.001	—.001	—.001	.000	.002	—.001	.001	.000	.002	.002	.001	.000	—.001	.001	—.001	.001
42	.0045	.018	—.001	—.001	—.001	.001	.002	—.001	.001	.000	.001	.002	.001	.001	.000	.000	—.001	.001
40	.0045	.018	—.004	—.002	—.002	.001	.001	—.001	.001	.000	.002	.002	.001	.000	.000	.000	—.002	.000
38	.0045	.017	—.002	—.001	—.001	.001	.002	—.002	.001	.001	.003	.002	.002	.001	.000	.002	—.001	.001
36	.0045	.017	—.002	—.001	—.002	.001	.002	—.002	.001	.001	.003	.002	.002	.001	.000	.001	—.002	.000
34	.0045	.016	—.001	.000	.000	.001	.003	—.001	.001	.001	.004	.002	.004	.002	.000	.002	—.001	.001
32	.0042	.016	—.001	—.001	.000	.001	.001	.000	.000	.000	.002	.003	.003	.002	.000	.002	—.001	.001
30	.0042	.016	—.001	—.001	—.001	.001	.001	—.001	.000	.001	.002	.004	.003	.001	—.001	.002	—.001	.001
28	.0047	.016	—.001	—.001	—.001	.001	.002	—.001	.000	.001	.002	.003	.003	.001	—.001	.002	—.001	.001
26	.0045	.016	—.001	—.001	—.001	.001	.002	—.001	.000	.001	.004	.003	.002	.001	—.001	.002	—.001	.000
24	.0045	.016	—.001	—.001	—.001	.000	.002	—.001	.000	.001	.000	.003	.002	.001	—.001	.002	—.001	—.001
22	.0045	.015	.000	.000	.000	.001	.003	.000	.001	.002	.001	.004	.003	.001	.000	.002	.000	.000
20	.0047	.018	—.004	—.004	—.003	—.002	.000	—.003	—.002	—.001	—.003	.001	—.001	—.002	—.003	—.002	—.003	—.003
18	.0045	.015	—.002	—.001	—.001	.001	.003	.000	.000	.001	.000	.003	.002	.000	—.001	.001	—.001	.000
16	.0045	.011	.002	.002	.002	.004	.005	.003	.004	.004	.004	.006	.005	.004	.003	.005	.003	.004
14	.0045	.012	.000	.001	.001	.003	.004	.002	.002	.003	.003	.003	.004	.002	.001	.003	.002	.003
12	.0045	.012	.000	—.001	.001	.003	.003	.001	.002	.003	.003	.003	.004	.002	.001	.003	.001	.002
10	.0045	.013	—.002	—.002	.000	.000	.001	.000	.002	.002	.001	.002	.001	.001	—.002	.002	—.001	.001
8	.0045	.013	—.003	—.002	—.001	.000	.000	.000	.003	.001	.001	.002	.001	.001	—.002	.002	—.001	.001
6	.005	.013	—.003	—.002	—.002	.000	.000	.000	.003	.001	.000	.002	.003	.001	—.002	.002	—.001	.001
4	....	.013	—.003	—.002	—.002	.000	.000	.000	.002	.001	.001	.003	.002	.000	—.002	.002	—.001	.001
2	....	.013	—.004	—.003	—.002	.000	—.001	—.001	.002	.001	.001	.002	.002	.000	—.002	.001	—.001	.000
1	....	.012	—.004	—.002	—.003	—.001	—.001	.000	.003	.002	.002	.002	.002	.000	—.002	.002	—.001	—.001

Table of enlargements of 8-inch muzzle-loading rifle, No. 1, M. I. (steel tube)—Continued.

Inches from muzzle.	Original play of tube.	Original diameter of bore.	Enlargements, including "setting up" of tube, after—															
			179 rounds—cold.	199 rounds—cold.	219 rounds—cold.	239 rounds—cold.	259 rounds—cold.	280 rounds—warm.	300 rounds—warm.	320 rounds—cold.	340 rounds—warm.	360 rounds—cold.	380 rounds—cold.	400 rounds—warm.	420 rounds—cold.	440 rounds—warm.	460 rounds—cold.	500 rounds—cold.
101	0. 005	8. 022	0. 022	0. 022	0. 023	0. 025	0. 026	0. 026	0. 028	0. 026	0. 027	0. 027	0. 027	0. 028	0. 028	0. 029	0. 028	0. 028
100	. 0045	. 022	. 022	. 022	. 023	. 025	. 026	. 026	. 028	. 025	. 027	. 026	. 026	. 028	. 028	. 028	. 027	. 027
99	. 0045	. 022	. 022	. 022	. 023	. 024	. 026	. 026	. 027	. 025	. 027	. 026	. 026	. 028	. 028	. 028	. 027	. 027
98	. 0045	. 022	. 022	. 022	. 023	. 024	. 024	. 026	. 027	. 025	. 027	. 025	. 026	. 028	. 027	. 028	. 027	. 027
97	. 0045	. 022	. 022	. 022	. 023	. 024	. 024	. 025	. 027	. 025	. 027	. 025	. 025	. 028	. 027	. 028	. 026	. 026
96	. 004	. 022	. 022	. 022	. 022	. 023	. 024	. 027	. 028	. 025	. 027	. 025	. 025	. 028	. 026	. 028	. 026	. 027
95	. 0045	. 022	. 022	. 022	. 022	. 023	. 024	. 027	. 027	. 024	. 027	. 025	. 026	. 028	. 027	. 027	. 027	. 027
94	. 0045	. 022	. 021	. 021	. 022	. 023	. 023	. 027	. 028	. 026	. 027	. 026	. 027	. 028	. 027	. 028	. 027	. 028
93	. 004	. 022	. 021	. 021	. 022	. 023	. 023	. 027	. 028	. 026	. 027	. 026	. 028	. 028	. 028	. 032	. 029	. 031
92	. 004	. 022	. 020	. 019	. 021	. 022	. 022	. 026	. 028	. 026	. 026	. 026	. 028	. 028	. 028	. 031	. 029	. 032
91	. 0037	. 022	. 020	. 019	. 021	. 022	. 023	. 025	. 028	. 026	. 028	. 027	. 029	. 030	. 031	. 033	. 031	. 032
90	. 0042	. 022	. 018	. 018	. 021	. 022	. 023	. 027	. 029	. 026	. 028	. 026	. 028	. 030	. 030	. 031	. 030	. 028
89	. 004	. 022	. 018	. 019	. 021	. 022	. 022	. 028	. 028	. 026	. 027	. 026	. 028	. 028	. 028	. 030	. 029	. 029
88	. 004	. 021	. 019	. 019	. 022	. 025	. 024	. 029	. 030	. 028	. 029	. 028	. 029	. 032	. 029	. 031	. 029	. 029
87	. 004	. 021	. 018	. 019	. 022	. 025	. 027	. 029	. 031	. 028	. 029	. 028	. 029	. 032	. 030	. 031	. 029	. 029
86	. 0042	. 021	. 018	. 019	. 023	. 026	. 029	. 029	. 031	. 027	. 029	. 028	. 029	. 032	. 030	. 031	. 029	. 029
85	. 0045	. 021	. 018	. 019	. 023	. 025	. 028	. 028	. 029	. 026	. 029	. 027	. 027	. 029	. 029	. 029	. 027	. 027
84	. 0045	. 021	. 018	. 019	. 023	. 024	. 027	. 028	. 029	. 026	. 028	. 027	. 026	. 029	. 027	. 028	. 026	. 026
83	. 0047	. 021	. 018	. 019	. 023	. 022	. 026	. 029	. 029	. 024	. 028	. 025	. 026	. 027	. 029	. 029	. 026	. 026
82	. 0047	. 021	. 017	. 019	. 019	. 023	. 022	. 025	. 025	. 023	. 025	. 024	. 024	. 026	. 027	. 028	. 025	. 025
81	. 0047	. 021	. 016	. 016	. 019	. 020	. 020	. 023	. 024	. 019	. 024	. 023	. 023	. 025	. 025	. 025	. 023	. 023
80	. 0047	. 021	. 014	. 014	. 017	. 018	. 018	. 019	. 023	. 018	. 023	. 019	. 021	. 023	. 023	. 024	. 023	. 023
78	. 0047	. 021	. 013	. 012	. 013	. 019	. 015	. 020	. 019	. 015	. 017	. 019	. 016	. 017	. 018	. 019	. 017	. 017
76	. 005	. 021	. 011	. 011	. 014	. 017	. 014	. 015	. 018	. 014	. 015	. 016	. 014	. 017	. 017	. 017	. 015	. 015
74	. 005	. 021	. 011	. 009	. 014	. 016	. 013	. 014	. 016	. 012	. 014	. 017	. 014	. 016	. 016	. 015	. 013	. 013
72	. 0047	. 021	. 006	. 006	. 007	. 009	. 009	. 009	. 012	. 008	. 009	. 014	. 009	. 010	. 012	. 012	. 009	. 009
70	. 005	. 021	. 004	. 003	. 006	. 007	. 007	. 007	. 009	. 006	. 009	. 007	. 007	. 009	. 009	. 009	. 007	. 007
68	. 005	. 021	. 004	. 004	. 004	. 007	. 006	. 006	. 009	. 006	. 008	. 005	. 006	. 007	. 009	. 009	. 006	. 006
66	. 0047	. 020	. 005	. 003	. 005	. 006	. 007	. 006	. 009	. 005	. 009	. 005	. 007	. 008	. 008	. 008	. 005	. 005
64	. 0045	. 020	. 004	. 002	. 004	. 004	. 004	. 004	. 007	. 004	. 005	. 004	. 004	. 005	. 007	. 007	. 004	. 004
62	. 0045	. 020	. 003	. 002	. 003	. 004	. 004	. 004	. 007	. 004	. 005	. 004	. 004	. 005	. 006	. 006	. 004	. 003
60	. 0045	. 019	. 004	. 002	. 004	. 005	(45) . 005	. 005	. 008	. 005	. 006	. 005	. 005	. 006	. 006	. 006	. 005	. 004
58	. 0042	. 019	. 004	. 002	. 004	. 005	. 005	. 005	. 007	. 005	. 006	. 005	. 004	. 006	. 006	. 006	. 004	. 004
56	. 0047	. 018	. 007	. 002	. 008	. 008	. 008	. 008	. 011	. 007	. 009	. 007	. 008	. 010	. 010	. 010	. 006	. 007

54	.0047	.019	.005	.004	.005	.006	.006	.005	.008	.004	.006	.005	.005	.006	.006	.008	.004	.005
52	.0047	.019	.004	.003	.005	.005	.005	.005	.008	.004	.005	.004	.005	.006	.006	.006	.004	.004
50	.0047	.019	.004	.002	.005	.006	.005	.005	.008	.004	.006	.004	.005	.006	.006	.006	.004	.004
48	.005	.019	.003	.001	.003	.005	.003	.004	.006	.002	.005	.002	.003	.005	.005	.004	.002	.002
46	.005	.018	.002	.000	.002	.004	.004	.004	.006	.002	.006	.003	.002	.005	.006	.005	.002	.003
44	.005	.018	.002	.000	.002	.004	.002	.003	.006	.001	.003	.002	.002	.004	.004	.004	.002	.002
42	.0045	.018	.002	.000	.001	.002	.002	.002	.006	.002	.003	.002	.002	.003	.004	.004	.002	.002
40	.0045	.018	.001	.001	.002	.002	.002	.002	.005	.001	.003	.001	.002	.002	.003	.004	.001	.001
38	.0045	.017	.002	.002	.002	.002	.002	.003	.007	.002	.003	.002	.002	.003	.003	.003	.002	.002
36	.0045	.017	.001	.002	.001	.001	.002	.002	.004	.002	.003	.002	.002	.003	.003	.003	.001	.001
34	.0045	.016	.002	.002	.002	.002	.002	.003	.004	.002	.004	.002	.002	.003	.004	.004	.002	.002
32	.0042	.016	.001	.001	.002	.003	.002	.003	.004	.002	.003	.002	.002	.003	.004	.003	.002	.002
30	.0042	.016	.001	.001	.002	.003	.001	.002	.004	.001	.003	.002	.002	.003	.004	.003	.001	.001
28	.0047	.016	.001	.001	.002	.002	.002	.002	.004	.001	.003	.001	.002	.003	.004	.003	.001	.001
26	.0045	.016	.001	.001	.001	.002	.002	.002	.004	.001	.003	.001	.002	.003	.004	.003	.001	.001
24	.0045	.016	.001	.001	.001	.002	.002	.002	.004	.001	.003	.001	.002	.003	.004	.003	.001	.001
22	.0045	.015	.002	.002	.002	.003	.003	.003	.005	.002	.004	.002	.003	.004	.004	.004	.002	.002
20	.0047	.018	—.001	—.001	—.001	.000	—.001	—.001	.002	—.001	.001	—.001	.000	.001	.001	.001	—.001	—.002
18	.0045	.015	.001	.002	.002	.003	.002	.002	.005	.002	.004	.001	.003	.004	.003	.003	.002	.001
16	.0045	.011	.005	.006	.006	.006	.006	.006	.008	.005	.008	.005	.006	.007	.007	.007	.005	.005
14	.0045	.012	.003	.003	.004	.005	.004	.005	.007	.004	.006	.003	.003	.006	.005	.006	.003	.003
12	.0045	.012	.003	.003	.003	.004	.003	.003	.006	.003	.006	.003	.003	.005	.005	.005	.003	.003
10	.0045	.013	.001	.001	.002	.002	.002	.002	.005	.001	.004	.002	.002	.004	.003	.003	.001	.001
8	.0045	.013	.001	.001	.001	.002	.002	.002	.005	.001	.004	.002	.002	.004	.003	.002	.001	.001
6	.005	.013	.001	.001	.001	.002	.001	.002	.005	.001	.004	.001	.002	.003	.003	.002	.001	.001
4	....	.013	.000	.001	.001	.002	.002	.002	.005	.001	.002	.001	.002	.003	.003	.002	.001	.001
2	....	.013	.000	.001	.001	.001	.001	.002	.005	.000	.002	.001	.001	.003	.002	.002	.001	.001
1	....	.012	—.001	.000	.001	.002	.001	.002	.005	.001	.003	.002	.002	.004	.003	.003	.002	.001

Record of firing with 8-*inch muzzle-loading rifle No.* 1, *muzzle insertion* (*steel tube*), *at Sandy Hook, N. J., from June* 10 *to August* 15, 1884.

	Number of fire.	Time.	Powder.			Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity, 110 feet from muzzle.	Recoil.	Wind, strength, and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.			Kind.	Weight.						
		1884.			Lbs.			° ′	Pounds.	Feet.	Feet.		
Barometer, 29.880; thermometer, 70; humidity, 77.	1	June 10	E. V. L	Du Pont's hexagonal density, 1.780; granulation, 72.	25	Butler (new)	180	0	29,000	1,247	2.16	From front and left 87°. 18 miles an hour.	Fired into sand butt.
	2	June 10	E. V. H		25	..do	180	0	35,000	1,313	2.00		Do.
	3	June 10	E. V. L		25	..do	180	0	29,500	1,266	1.75		Do.
	4	June 10	E. V. H		25	..do	180	0	37,500	1,300	1.67		Fired into sand butt. Gun washed out, examined, and star-gauged.
Barometer, 30.067; thermometer, 61.2; humidity, 83.	5	June 11	E. V. L		30	..do	181	0	37,000	1,335	2.42	From front and left 87°. 27 miles an hour.	Fired into sand butt.
	6	June 11	E. V. K		30	..do	181	0	40,500	1,362	2.37		Do.
	7	June 11	E. V. M		30	..do	181	0	27,000	1,286	2.04		Do.
	8	June 11	..do		35	..do	181	0	30,250	1,371	2.46		Do.
	9	June 11	..do		35	..do	181	0	29,500	1,366	2.33		Fired into sand butt. Gun washed out, examined, and star-gauged.
Barometer, 30.053; thermometer, 61.4; humidity, 82.	10	June 11	..do		35	..do	182	0	28,500	1,382	2.42	From front and left 87°. 30 miles an hour.	Do.
	11	June 11	..do		35	..do	182	0	25,500	1,369	2.44		Do.
	12	June 11	..do		35	..do	182	0	32,000	1,377	2.37		Do.
	13	June 11	..do		35	..do	182	0	30,250	1,355	2.29		Do.
	14	June 11	..do		35	..do	182	0	30,750	1,367	2.16		Do.
	15	June 11	E. V. N		35	..do	182	0	30,750	1,369	2.08		Do.
	16	June 11	..do		35	..do	182	0	30,250	1,367	2.08		Do.
	17	June 11	..do		35	..do	182	0	27,500	1,355	2.08		Do.
	18	June 11	..do		35	..do	182	0	30,000	1,365	2.21		Do.
	19	June 11	..do		35	..do	182	0	31,500	1,366	2.21		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.

Barometer, 30.008; thermometer, 62.4; humidity, 86.	20	June 12	E. V. M.	Du Pont's hexagonal density, 1.750; granulation, 72.	35	....do	183	0	....	....	3.08	From front and left 87°. 7 miles an hour.	Fired into sand butt.
	21	June 12	...do		35	....do	183	0	....	....	3.16		Do.
	22	June 12	...do		35	....do	183	0	....	....	3.08		Do.
	23	June 12	...do		35	....do	183	0	....	....	3.00		Do.
	24	June 12	...do		35	....do	183	0	....	....	2.75		Do.
	25	June 12	...do		35	....do	183	0	....	....	2.58		Do.
	26	June 12	...do		35	....do	183	0	....	....	2.58		Do.
	27	June 12	...do		35	....do	183	0	....	....	2.50		Do.
	28	June 12	...do		35	....do	183	0	....	....	2.42		Do.
	29	June 12	...do		35	....do	183	0	29,000	1 375	2.50		Do.
	30	June 12	...do		35	....do	184	0	....	....	2.58		Do.
	31	June 12	...do		35	....do	184	0	....	....	2.50		Do.
	32	June 12	...do		35	....do	184	0	....	....	2.42		Do.
	33	June 12	...do		35	....do	184	0	....	....	2.33		Do.
	34	June 12	...do		35	....do	184	0	....	....	2.25		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.
Barometer, 30.008; thermometer, 62.4; humidity, 86.	35	June 12		Du Pont's hexagonal E. V. N.; density, 1.750; granulation, 72.	35	....do	184	0	....	....	2.08	From front and left 87°. 7 miles an hour.	Do.
	36	June 12			35	....do	184	0	....	....	2.08		Do.
	37	June 12			35	....do	184	0	....	....	2.08		Do.
	38	June 12			35	....do	184	0	....	....	2.08		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.
Barometer, 29.988; thermometer, 66.8; humidity, 85.	39	June 12			35	....do	184	0	26,000	1,354	1.92	From rear and left 48°. 6 miles an hour.	Fired into sand butt.
	40	June 12			35	....do	183	0	....	....	2.38		Do.
	41	June 12			35	....do	183	0	....	....	2.25		Do.
	42	June 12			35	....do	183	0	....	....	2.25		Do.
	43	June 12			35	....do	183	0	....	....	2.00		Do.
	44	June 12			35	....do	183	0	....	....	2.25		Do.
	45	June 12			35	....do	183	0	....	....	2.16		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.			Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity, 110 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.							
		1884.		Lbs.		Lbs.		° ′	Pounds.	Feet.	Feet.		
Barometer, 29.988; thermometer, 66.8; humidity, 85.	46	June 12	Du Pont's hexagonal E V. N.; density, 1.750; granulation, 72.	35	Butler (new)	183		0	....	....	2.25	From rear and left 48°, 6 miles an hour.	Fired into sand butt.
	47	June 12		35	...do	183		0	....	....	2.08		Do.
	48	June 12		35	...do	183		0	....	....	2.16		Do.
	49	June 12		35	...do	183		0	30,250	1,364	2.08		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.
Barometer, 30.216; thermometer, 60.8; humidity, 86.	50	June 13		35	...do	183		0	....	....	3.00	From front and left 87°. 28 miles an hour.	Fired into sand butt.
	51	June 13		35	...do	183		0	....	....	2.83		Do.
	52	June 13		35	...do	183		0	....	....	2.67		Do.
	53	June 13		35	...do	183		0	....	....	2.50		Do.
	54	June 13		35	...do	183		0	....	....	2.42		Do.
	55	June 13		35	...do	183		0	....	....	2.25		Do.
	56	June 13		35	...do	183		0	....	....	2.25		Do.
	57	June 13		35	...do	183		0	....	....	2.16		Do.
	58	June 13		35	...do	183		0	....	....	2.16		Do.
	59	June 13		35	...do	183		0	34,000	1,386	2.16		Fired into sand butt. Gun washed out, examined, impressions taken, and star gauged.
	60	June 13		35	...do	181		0	....	....	2.16		Fired into sand butt.
	61	June 13		35	...do	181		0	....	....	2.16		Do.
	62	June 13		35	...do	181		0	....	....	2.16		Do.
	63	June 13		35	...do	181		0	....	....	2.16		Do.
	64	June 13		35	...do	181		0	....	....	2.16		Do.

	65	June 13	Du Pont's hexagonal, E. V. N. Density, 1.750; granulation, 72.	35	...do	181	0	....	....	2.16		Do.
	66	June 13		35	...do	181	0	....	....	1.92		Do.
	67	June 13		35	...do	181	0	....	....	2.16		Do.
	68	June 13		35	...do	181	0	....	....	2.16		Do.
	69	June 13		35	...do	181	0	29,250	1,366	2.16		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 30.483; thermometer, 60.2; humidity, 59.	70	June 14		35	...do	183	0	....	....	2.16	From front and left 87°. 36 miles an hour.	Fired into sand butt.
	71	June 14		35	...do	183	0	....	....	2.25		Do.
	72	June 14		35	...do	183	0	....	....	2.00		Do.
	73	June 14		35	...do	183	0	....	....	2.08		Do.
	74	June 14		35	...do	183	0	....	....	2.16		Do.
	75	June 14		35	...do	183	0	....	....	2.16		Do.
	76	June 14		35	...do	183	0	....	....	2.16		Do.
	77	June 14		35	...do	183	0	....	....	2.00		Do.
	78	June 14		35	...do	183	0	....	....	2.16		Do.
	79	June 14		35	...do	183	0	30,750	1,362	2.16		Do.
	80	June 14		35	...do	182	0	....	....	2.25		Do.
	81	June 14		35	...do	182	0	....	....	2.25		Do.
	82	June 14		35	...do	182	0	....	....	2.16		Do.
	83	June 14		35	...do	182	0	....	....	2.25		Do.
	84	June 14		35	...do	182	0	....	....	2.25		Do.
	85	June 14		35	...do	182	0	....	....	2.33		Do.
	86	June 14		35	...do	182	0	....	....	2.16		Do.
	87	June 14		35	...do	182	0	....	....	2.42		Do.
	88	June 14		35	...do	182	0	....	....	2.33		Do.
	89	June 14		35	do	182	0	31,250	1,378	2.42		Do.
	90	June 14		35	...do	184	0	....	....	2.33		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 110 feet from muzzle.	Recoil.	Wind, strength, and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 30.483; thermometer, 60.2; humidity, 50.	91	June 14	Du Pont's hexagonal, E. V. N. Density, 1.750; granulation, 72.	35	Butler (new).	184	0	....	....	2.16	From front and left 87°. 36 miles an hour.	Fired into sand butt.
	92	June 14		35	....do	184	0	....	....	2.58		Do.
	93	June 14		35	....do	184	0	....	....	2.42		Do.
	94	June 14		35	....do	184	0	....	....	2.25		Do.
	95	June 14		35	....do	184	0	....	....	2.33		Do.
	96	June 14		35	....do	184	0	....	....	2.16		Do.
	97	June 14		35	....do	184	0	....	....	2.33		Do.
	98	June 14		35	....do	184	0	....	....	2.00		Do.
	99	June 14		35	....do	184	0	29,750	1,363	2.42		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.948; thermometer, 73.3; humidity, 66.	100	June 19		35	....do	183	0	....	....	2.42	From front and right 3°. 8 miles an hour.	Fired into sand butt.
	101	June 19		35	....do	183	0	....	....	2.42		Do.
	102	June 19		35	....do	183	0	....	....	2.50		Do.
	103	June 19		35	....do	183	0	....	....	2.33		Do.
	104	June 19		35	....do	183	0	....	....	2.33		Do.
	105	June 19		35	....do	183	0	....	....	2.42		Do.
	106	June 19		35	....do	183	0	....	....	2.33		Do.
	107	June 19		35	....do	183	0	....	....	2.33		Do.
	108	June 19		35	....do	183	0	....	....	2.42		Do.
	109	June 19		35	....do	183	0	29,500	1,354	2.33		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.

Barometer, 29.948; thermometer, 73.3; humidity, 66.	110	June 19	Du Pont's hexagonal E. V. N.; density, 1.750; granulation, 72.	35	....do	180	0	....	....	2.33	From front and right 3°, 8 miles an hour.	Fired into sand butt.
	111	June 19		35	....do	180	0	....	....	2.33		Do.
	112	June 19		35	....do	180	0	....	....	2.16		Do.
	113	June 19		35	....do	180	0	....	....	2.16		Do.
	114	June 19		35	... do	180	0	....	....	2.25		Do.
	115	June 19		35	....do	180	0	....	....	2.16		Do.
	116	June 19		35	....do	180	0	....	....	2.16		Do.
	117	June 19		35	....do	180	0	....	....	2.00		Do.
	118	June 19		35	....do	180	0	....	....	2.25		Do.
	119	June 19		35	....do	180	0	31,500	1,370	2.16		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.972; thermometer, 69.7; humidity, 81.	120	June 20		35	....do	182	0	....	....	2.25	From front and left 15°, 7 miles an hour.	Fired into sand butt.
	121	June 20		35	....do	182	0	....	....	2.33		Do.
	122	June 20		35	....do	182	0	....	....	2.25		Do.
	123	June 20		35	....do	182	0	....	....	2.33		Do.
	124	June 20		35	....do	182	0	....	....	2.25		Do.
	125	June 20		35	....do	182	0	....	....	2.16		Do.
	126	June 20		35	....do	182	0	....	....	2.16		Do.
	127	June 20		35	....do	182	0	....	....	2.08		Do.
	128	June 20		35	....do	182	0	....	....	2.25		Do.
	129	June 20		35	....do	182	0	32,750	1,388	2.16		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.862; thermometer, 79.6; humidity, 73.	130	June 24	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	35	....do	181	0	25,750	1,309	2.58	From front and right 8°, 18 miles an hour.	Fired into sand butt.
	131	June 24		40	... do	181	0	29,250	1,356	2.42		Do.
	132	June 24		42	....do	181	0	30,250	1,393	2.75		Do.
	133	June 24		42	....do	181	0	23,500	1,397	2.92		Fired into sand butt. The disk used was probably abnormally hard; the pressure obtained from a cut of same length, afterwards obtained in testing machine, being about 30,000 pounds.
	134	June 24		42	....do	181	0	29,750	1,396	2.50		Fired into sand butt.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 110 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 29.853; thermometer, 79.3; humidity, 73.	135	June 25	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	45	Butler (new)	181	0	33, 750	1, 454	3. 42	From front and right 48°, 10 miles an hour.	Fired into sand butt.
	136	June 25		45	....do	181	0	33, 500	1, 441	3. 16		Do.
	137	June 25		43	....do	181	0	29, 500	1, 382	2. 83		Do.
	138	June 25		43	....do	181	0	32, 000	1, 398	2. 83		Do.
	139	June 25		43	....do	181	0	29, 750	1, 391	2. 58		Fired into sand butt. Gun washed out, examined, and star-gauged.
								(Crusher.)				
Barometer, 29.854; thermometer, 81; humidity, 66.	140	July 2	Du Pont's I. C., sphero-hexagonal; density, 1.815; granulation, 123.	35	....do	181	0	18, 100	Lost.	1. 67	From rear and right 87°, 12 miles an hour.	Fired into sand butt.
	141	July 2		40	....do	181	0	21, 600	1, 255	2. 16		Do.
	142	July 2		40	....do	181	0	21, 900	1, 248	2. 16		Do.
	143	July 2	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	42	....do	181	0	29, 400	1, 385	2. 42		Do.
	144	July 2		43	....do	181	0	30, 300	1, 389	2. 50		Do.
	145	July 2		45	....do	181	0	30, 900	1, 427	2, 67		Do.
	146	July 2		45	....do	181	0	....	....	2. 08		Do.
	147	July 2		45	....do	181	0	....	....	2. 33		Do.
	148	July 2		45	....do	181	0	....	....	2. 16		Do.
	149	July 2		45	....do	181	0	....	....	2. 42		Do.
	150	July 2		45	....do	185	0	....	....	2. 42		Do.

Barometer, 29.854; thermometer, 81; humidity, 66.	151	July	2	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	45	do	185	0			2. 25	From rear and right 87°. 12 miles an hour.	Do.
	152	July	2		45	do	185	0			2. 42		Do.
	153	July	2		45	do	185	0			2. 25		Do.
	154	July	2		45	do	185	0			2. 42		Do.
	155	July	2		45	do	185	0			2. 25		Do.
	156	July	2		45	do	185	0			2. 00		Do.
	157	July	2		45	do	185	0			1. 92		Do.
	158	July	2		45	do	185	0			2. 25		Do.
	159	July	2		45	do	184	0			2. 00		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.783; thermometer, 69 3; humidity, 70.	160	July	9		45	Butler (re-saboted).	183	0	26, 400	1, 352	2. 16	From rear and left 3°. 14 miles an hour.	Fired into sand butt.
	161	July	9		45	do	183	0			2. 16		Do.
	162	July	9		45	do	183	0			2. 00		Do.
	163	July	9		45	do	183	0			2. 16		Do.
	164	July	9		45	do	183	0			1. 83		Do.
	165	July	9		45	do	183	0			2. 00		Do.
	166	July	9		45	do	183	0			2. 08		Do.
	167	July	9		45	do	183	0			2. 08		Do.
	168	July	9		45	do	183	0			2. 42		Do.
	169	July	9		45	do	183	0			2. 33		Do.
	170	July	9		45	do	182	0			2. 08		Do.
	171	July	9		45	do	182	0			2. 42		Do.
	172	July	9		45	do	182	0			2. 25		Do.
	173	July	9		45	do	182	0			2. 08		Do.
	174	July	9		45	do	182	0			2. 25		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 108 feet 4 inches from muzzle.	Recoil.	Wind, strength, and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs.*		*Lbs.*	° '	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 29.783; thermometer, 69.3; humidity, 70.	175	July 9	Du Pont's hexagonal E. V. M.; density, 1.750; granulation, 72.	45	Butler (resaboted).	182	0	....	....	2.25	From rear and left 3°. 14 miles an hour.	Fired into sand butt.
	176	July 9		45	....do	182	0	....	....	2.33		Do.
	177	July 9		45	....do	182	0	....	....	2.16		Do.
	178	July 9		45	....do	182	0	....	....	2.16		Do.
	179	July 9		45	....do	182	0	....	....	2.16		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.829; thermometer, 66; humidity, 75.	180	July 10		45	....do	181	0	27,100	1,350	2.42	From rear and right 43°. 11 miles an hour.	Fired into sand butt.
	181	July 10		45	....do	181	0	....	....	2.42		Do.
	182	July 10		45	....do	181	0	....	....	2.33		Do.
	183	July 10		45	....do	181	0	....	....	2.42		Do.
	184	July 10		45	....do	181	0	....	....	2.42		Do.
	185	July 10		45	....do	181	0	....	....	2.50		Do.
	186	July 10		45	....do	181	0	....	....	2.42		Do.
	187	July 10		45	....do	181	0	....	....	2.42		Do.
	188	July 10		45	....do	182	0	....	....	2.16		Do.
	189	July 10		45	....do	182	0	....	....	2.42		Do.
	190	July 10		45	....do	180	0	....	....	2.42		Do.
	191	July 10		45	....do	180	0	....	....	2.44		Do.
	192	July 10		45	....do	180	0	....	....	2.33		Do.
	193	July 10		45	....do	180	0	....	....	2.42		Do.

Barometer, 29.829; thermometer, 66, humidity, 75.	194	July 10	Du Pont's hexagonal E. V. M.; density, 1,750; granulation, 72.	45	....do	180	0	....	....	2.33	From rear and right 43°. 11 miles an hour.	Fired into sand butt.
	195	July 10		45	....do	180	0	....	....	2.25		Do.
	196	July 10		45	....do	180	0	....	....	2.25		Do.
	197	July 10		45	....do	170	0	....	....	2.10		Do.
	198	July 10		45	....do	170	0	....	....	2.33		Do.
	199	July 10		45	....do	170	0	....	....	2.42		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 29.927; thermometer, 75.9; humidity, 72.	200	July 11		45	....do	183	0	28,400	1,376	2.16	From front. 14 miles an hour.	Fired into sand butt.
	201	July 11		45	....do	183	0	....	....	2.42		Do.
	202	July 11		45	....do	183	0	....	....	2.33		Do.
	203	July 11		45	....do	183	0	....	....	2.50		Do.
	204	July 11		45	....do	183	0	....	....	2.25		Do.
	205	July 11		45	....do	183	0	....	....	2.25		Do.
	206	July 11		45	....do	183	0	....	....	2.42		Do.
	207	July 11		45	....do	183	0	....	....	2.08		Do.
	208	July 11		45	....do	183	0	....	....	2.25		Do.
	209	July 11		45	....do	183	0	....	....	2.16		Do.
	210	July 11		45	....do	183	0	....	....	2.42		Do.
	211	July 11		45	....do	183	0	....	....	2.42		Do.
	212	July 11		45	....do	183	0	....	....	2.08		Do.
	213	July 11		45	....do	183	0	....	....	2.42		Do.
	214	July 11		45	....do	183	0	....	....	2.00		Do.
	215	July 11		45	....do	182	0	....	....	2.08		Do.
	216	July 11		45	....do	182	0	....	....	2.33		Do.
	217	July 11		45	....do	182	0	....	....	2.25		Do.
	218	July 11		45	....do	182	0	....	....	2.42		Do.
	219	July 11		45	....do	182	0	....	....	2.50		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.

Record of firing with 8-inch muzzle-loading rifle No. 1, *muzzle insertion (steel tube), at Sandy Hook, N. J., &c.*—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 108 feet 4 inches from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, &c.
			Kind.	Weight.	Kind.	Weight.						
		1884.		Lbs.		Lbs.	° ′	Pounds.	Feet.	Feet.		
Barometer, 29.899; thermometer, 77.2; humidity, 69.	220	July 11	Du Pont's hexagonal E. V. M; density, 1.750; granulation, 72.	45	Butler (resaboted).	182	0	32,800	1,429	2.75	From front. 18 miles an hour.	Fired into sand butt.
	221	July 11		45	....do	182	0	....	....	2.42		Do.
	222	July 11		45	....do	181	0	....	....	2.67		Do.
	223	July 11		45	....do	181	0	....	....	2.83		Do.
	224	July 11		45	....do	181	0	....	....	2.58		Do.
	225	July 11		45	....do	181	0	....	....	2.83		Do.
	226	July 11		45	....do	181	0	....	....	2.50		Do.
	227	July 11		45	....do	179	0	....	....	2.42		Do.
	228	July 11		45	....do	179	0	....	....	2.50		Do.
	229	July 11		45	....do	179	0	....	....	2.33		Do.
Barometer, 29.900; thermometer, 70.6; humidity, 89.	230	July 12		45	....do	178	0	....	....	3.08	From front and right 3°. 4 miles an hour.	Do.
	231	July 12		45	....do	184	0	....	....	2.25		Do.
	232	July 12		46	Butler (new).	179	0	....	....	2.33		Do.
	233	July 12		45	....do	179	0	....	....	2.42		Do.
	234	July 12		45	....do	179	0	....	....	2.58		Do.
	235	July 12		45	....do	179	0	....	....	2.50		Do.
	236	July 12		45	....do	179	0	....	....	2.58		Do.
	237	July 12		45	....do	180	0	....	....	2.58		Do.
	238	July 12		45	....do	180	0	....	....	2.42		Do.
	239	July 12		45	....do	180	0	....	....	2.25		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.

Barometer, 29.818; thermometer, 65.8; humidity, 59.	240	July 16	Du Pont's hexagonal E. V. M. Density, 1,750; granulation, 72.	45	....do	180	0	27,600	1,388	2.42	From rear and left, 3°; 12 miles an hour.	Fired into sand butt.
	241	July 16		45	....do	180	0	....	....	2.33		Do.
	242	July 16		45	....do	180	0	....	....	2.25		Do.
	243	July 16		45	....do	180	0	....	....	2.58		Do.
	244	July 16		45	....do	180	0	....	....	2.42		Do.
	245	July 16		45	....do	180	0	....	....	2.25		Do.
	246	July 16		45	....do	180	0	....	....	2.42		Do.
	247	July 16		45	....do	180	0	....	....	2.25		Do.
	248	July 16		45	....do	180	0	....	....	2,58		Do.
	249	July 16		45	....do	180	0	....	....	1.92		Do.
Barometer, 29.958; thermometer, 71; humidity, 71.	250	July 23		45	....do	184	0	....	....	2.00	From front and right, 48°; 4 miles an hour.	Do.
	251	July 23		45	....do	184	0	....	....	2.33		Do.
	252	July 23		45	....do	184	0	....	....	2.25		Do.
	253	July 23		45	....do	184	0	....	....	2.25		Do.
	254	July 23		45	....do	184	0	....	....	2.16		Do.
	255	July 23		45	....do	184	0	....	....	2.16		Do.
	256	July 33		45	....do	184	0	....	....	2.00		Do.
	257	July 23		45	....do	184	0	....	....	2.33		Do.
	258	July 23		45	....do	183	0	....	....	2.08		Do.
	259	July 23		45	....do	183	0	....	....	2.42		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken of bore.
Barometer, 30.028; thermometer, 79.8; humidity, 55.	260	Aug. 1	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	Butler (rossboted).	180	0	31,900	1,389	2.00	From front and right, 48°; 9 miles an hour.	Fired into sand butt.
	261	Aug. 1		35	....do	180	0	34,400	1,408	2.16		Do.
	262	Aug. 1		35	....do	180	0	33,800	1,402	2.16		Do.
	263	Aug. 1		35	....do	180	0	29,300	1,354	1.83		Do.
	264	Aug. 1		35	....do	180	0	29,100	1,355	1.92		Do.
	265	Aug. 1		35	....do	180	0	30,900	1,384	1.92		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength, and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs.*		*Lbs.*	°	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 30.028; thermometer, 79.8; humidity, 55.	266	Aug. 1	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	Butler (resaboted).	180	0	32,700	1,406	2.16	From front and right, 48°; 6 miles an hour.	Fired into sand butt.
	267	Aug. 1		35	....do	180	0	30,300	1,374	1.83		Do.
	268	Aug. 1		35	....do	180	0	30,400	1,368	2.00		Do.
	269	Aug. 1		35	....do	180	0	28,500	1,362	2.00		Do.
Barometer, 30.190; thermometer, 68; humidity, 86.	270	Aug. 2		35	....do	180	0	....	....	2.00	From rear and left, 48°; 6 miles an hour.	Do.
	271	Aug. 2		35	....do	180	0	....	....	2.08		Do.
	272	Aug. 2		35	....do	181	0	....	....	1.83		Do.
	273	Aug. 2		35	....do	181	0	....	....	2.08		Do.
	274	Aug. 2		35	....do	181	0	....	....	1.83		Do.
	275	Aug. 2		35	....do	181	0	....	....	2.33		Do.
	276	Aug. 2		35	....do	181	0	....	....	2.16		Do.
	277	Aug. 2		35	....do	181	0	....	....	2.08		Do.
	278	Aug. 2		35	....do	181	0	....	....	2.00		Do.
	279	Aug. 2		35	....do	181	0	....	....	2.16		Do.
	280	Aug. 2		35	....do	181	0	....	....	2.00		Do.
	281	Aug. 2		35	....do	182	0	30,350	1,370	1.92		Do.
	282	Aug. 2		35	....do	182	0	....	....	2.08		Do.
	283	Aug. 2		35	....do	182	0	....	....	2.25		Do.
	284	Aug. 2		35	....do	182	0	....	....	2.25		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.

Barometer, 30.190; thermometer, 68; humidity, 86.	285	Aug. 2	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	....do	182	0	....	....	2.25	From rear and left, 48°; 6 miles an hour.	Do
	286	Aug. 2		35	....do	182	0	....	....	1.83		Do.
	287	Aug. 2		35	....do	182	0	....	....	2.00		Do.
	288	Aug. 2		35	....do	182	0	....	....	2.00		Do.
	289	Aug. 2		35	....do	182	0	....	....	2.00		Do.
	290	Aug. 2		35	....do	183	0	....	....	2.16		Do.
	291	Aug. 2		35	.. do	183	0	....	....	2.00		Do.
	292	Aug. 2		35	....do	183	0	....	....	2.16		Do.
	293	Aug. 2		35	....do	183	0	....	....	2.25		Do.
	294	Aug. 2		35	....do	183	0	....	....	2.08		Do.
	295	Aug. 2		35	....do	182	0	....	....	1.83		Do.
	296	Aug. 2		35	....do	183	0	....	....	2.00		Do.
	297	Aug. 2		35	....do	179	0	....	....	1.83		Do.
	298	Aug. 2		35	....do	179	0	....	....	2.33		Do.
	299	Aug. 2		35	....do	179	0	....	....	1.87		Do.
	300	Aug. 2		35	.. do	179	0	....	....	2.00		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 30.179; thermometer, 74.2; humidity, 59.	301	Aug. 2		35	Butler (old).	178	0	30, 250	1, 369	1.16	From front, 8 miles an hour.	Fired into sand butt.
	302	Aug. 2		35	....do	178	0	....	....	2.25		Do.
	303	Aug. 2		35	....do	178	0	....	....	2.00		Do.
	304	Aug. 2		35	....do	178	0	....	....	2.16		Do.
	305	Aug. 2		35	Butler(new).	180	0	....	....	2.08		Do.
	306	Aug. 2		35	....do	180	0	....	....	2.00		Do.
	307	Aug. 2		35	...do	181	0	....	....	1.83		Do.
	308	Aug. 2		35	....do	181	0	....	....	2.08		Do.
	309	Aug. 2		35	... do	181	0	....	....	1.83		Do.
	310	Aug. 2		35	....do	181	0	....	....	2.33		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 109 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		Lbs.		Lbs.	° ′	Pounds.	Feet.	Feet.		
Barometer, 30.179; thermometer, 74.2; humidity, 59.	311	Aug. 2	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	Butler (new)	182	0	....	....	2.08	From front, 8 miles an hour.	Fired into sand butt.
	312	Aug. 2		35	....do	182	0	....	....	2.16		Do.
	313	Aug. 2		35	....do	182	0	....	....	1.83		Do.
	314	Aug. 2		35	....do	182	0	....	....	2.50		Do.
	315	Aug. 2		35	....do	182	0	....	....	2.08		Do.
	316	Aug. 2		35	....do	182	0	....	....	2.08		Do.
	317	Aug. 2		35	....do	182	0	....	....	2.16		Do.
	318	Aug. 2		35	....do	182	0	....	....	2.16		Do.
	319	Aug. 2		35	....do	183	0	....	....	2.16		Do.
	320	Aug. 2		35	....do	183	0	....	....	2.00		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 30.007; thermometer, 77.3; humidity, 64.	321	Aug. 6		35	Butler (re-saboted).	182	0	31,950	1,385	2.16	From rear and right, 43°; 8 miles an hour.	Fired into sand butt.
	322	Aug. 6		35	....do	182	0	....	....	2.42		Do.
	323	Aug. 6		35	....do	182	0	....	....	2.33		Do.
	324	Aug. 6		35	....do	182	0	....	....	2.08		Do.
	325	Aug. 6		35	....do	182	0	....	....	2.00		Do.
	326	Aug. 6		35	....do	182	0	....	....	2.16		Do.
	327	Aug. 6		35	....do	182	0	....	....	2.33		Do.
	328	Aug. 6		35	....do	182	0	....	....	2.08		Do.
	329	Aug. 6		35	....do	182	0	....	....	2.16		Do.

Barometer, 30.007; thermometer, 77.3; humidity, 64.	330	Aug. 6	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 128.	35	....do	182	0			2.58	From rear and right 43°, 8 miles an hour.	Do.
	331	Aug. 6		35	....do	182	0			2.33		Do.
	332	Aug. 6		35	....do	182	0			2.42		Do.
	333	Aug. 6		35	....do	182	0			2.50		Do.
	334	Aug. 6		35	....do	182	0			2.33	From front and right 48°, 8 miles an hour.	Do.
	335	Aug. 6		35	.. do	182	0			2.50		Do.
	336	Aug. 6		35	....do	182	0			2.25		Do.
	337	Aug. 6		35	....do	182	0			2.67		Do.
	338	Aug. 6		35	....do	182	0			2.16		Do.
	339	Aug. 6		35	....do	182	0			2.33		Do.
	340	Aug. 6		35	....do	182	0			2.42		Do.
	341	Aug. 6		35	....do	181	0	20,100	1,365	2.42		Do.
	342	Aug. 6		35	....do	181	0			2.33		Do.
	343	Aug. 6		35	....do	181	0			2.58		Do.
	344	Aug. 6		35	....do	181	0			2.42		Do.
	345	Aug. 6		35	....do	181	0			2.42		Do.
	346	Aug. 6		35	... do	181	0			2.25		Do.
	347	Aug. 6		35	....do	181	0			2.25		Do.
	348	Aug. 6		35	....do	181	0			2.42		Do.
	349	Aug. 6		35	... do	181	0			2.16		Do.
	350	Aug. 6		35	....do	181	0			2.33		Do.
	351	Aug. 6		35	....do	181	0			2.00		Do.
	352	Aug. 6		35	....do	181	0			2.50		Do.
	353	Aug. 6		35	... do	181	0			2.42		Do.
	354	Aug. 6		35	....do	181	0			2.25		Do.
	355	Aug. 6		35	....do	181	0			2.50		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 109 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 30 007; thermometer, 77.3; humidity, 64—Continued.	356	Aug. 6	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 123.	35	Butler (resaboted).	181	0	....	....	2. 33	From front and right 48°, 8 miles an hour.	Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
	357	Aug. 6		35	....do	181	0	....	....	2. 75		Do.
	358	Aug. 6		35	....do	181	0	....	....	2. 42		Do.
	359	Aug. 6		35	....do	181	0	....	....	2. 58		Do.
	360	Aug. 6		35	....do	181	0	....	....	2. 50		Do.
Barometer, 30.149; thermometer, 74.6; humidity, 66.	361	Aug. 13		35	....do	183	0	30, 750	1, 376	2. 25	From front and left 43°. 7 miles an hour.	Do.
	362	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	363	Aug. 13		35	....do	183	0	....	....	2. 33		Do.
	364	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	365	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	366	Aug. 13		35	....do	183	0	....	....	2. 33		Do.
	367	Aug. 13		35	....do	183	0	....	....	2. 58		Do.
	368	Aug. 13		35	....do	183	0	....	....	2. 42		Do.
	369	Aug. 13		35	....do	183	0	....	....	2. 58		Do.
	370	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	371	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	372	Aug. 13		35	....do	183	0	....	....	2. 58		Do.
	373	Aug. 13		35	....do	183	0	....	....	2. 50		Do.
	374	Aug. 13		35	....do	183	0	....	....	2. 67		Do.

	375	Aug. 13	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 123.	35	....do	183	0			2.58		Do.
	376	Aug. 13		35	....do	183	0			2.50		Do.
	377	Aug. 13		35	....do	183	0			2.42		Three pins holding right flange of front transom broken off; repaired.
	378	Aug. 13		35	....do	183	0			2.67		Fired into sand butt.
	379	Aug. 13		35	....do	183	0			2.58		Do.
	380	Aug. 13		35	....do	183	0			2.33		Gun washed out, examined, star-gauged, and impressions taken of bore.
Barometer, 30.149; thermometer, 73.4; humidity, 69.	381	Aug. 14		35	....do	181	0	26,650	1,325	2.92	From rear and right 48°. 7 miles an hour.	Fired into sand butt.
	382	Aug. 14		35	....do	181	0			2.42		Do.
	383	Aug. 14		35	....do	181	0			2.75		Do.
	384	Aug. 14		35	....do	181	0			2.67		Do.
	385	Aug. 14		35	....do	181	0			2.67		Do.
	386	Aug. 14		35	....do	181	0			2.50		Do.
	387	Aug. 14		35	....do	181	0			2.67		Do.
	388	Aug. 14		35	....do	181	0			2.67		Do.
	389	Aug. 14		35	....do	181	0			2.50		Do.
	390	Aug. 14		35	....do	181	0			2.42		Do.
	391	Aug. 14		35	....do	181	0			2.42		Do.
	392	Aug. 14		35	....do	181	0			2.75		Do.
	393	Aug. 14		35	....do	181	0			2.50		Do.
	394	Aug. 14		35	....do	181	0			2.00		Do.
	395	Aug. 14		35	....do	181	0			2.50		Do.
	396	Aug. 14		35	....do	181	0			2.75		Do.
	397	Aug. 14		35	....do	181	0			2.75		Do.
	398	Aug. 14		35	....do	181	0			2.58		Do.
	399	Aug. 14		35	....do	180	0			2.67		Do.
	400	Aug. 14		35	....do	180	0			2.58		Do.

Record of firing with 8-inch muzzle loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore. (Crusher.).	Instrumental velocity, 109 feet from muzzle.	Recoil.	Wind strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		Lbs.		Lbs.	° ′	Pounds.	Feet.	Feet.		
Barometer, 30.149; thermometer, 70; humidity, 69.	401	Aug. 14	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 125.	35	Butler (resaboted.)	180	0	29,100	1,370	2.16	From rear and right 43°. 7 miles an hour.	Gun washed out, examined, star-gauged, and impressions taken of bore.
	402	Aug. 14		35	....do	180	0	....	....	2.42		Fired into sand butt.
	403	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	404	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	405	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	406	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	407	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	408	Aug. 14		35	....do	180	0	....	....	2.67		Do.
	409	Aug. 14		35	....do	180	0	....	....	2.42		Do.
	410	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	411	Aug. 14		35	....do	180	0	....	....	2.50		Do.
	412	Aug. 14		35	....do	180	0	....	....	2.67		Do.
	413	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	414	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	415	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	416	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	417	Aug. 14		35	....do	182	0	....	....	2.67		Do.
	418	Aug. 14		35	....do	182	0	....	....	2.67		Do.
	419	Aug. 14		35	....do	182	0	....	....	2.67		Do.

Barometer, 30.149; thermometer, 73.4; humidity, 69.	420	Aug. 14	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	....do	183	0	....	....	2.58	From front and left, 43°; 4 miles an hour.	Do.
	421	Aug. 14		35	....do	182	0	30,550	1 383	2.83		Do.
	422	Aug. 14		35	....do	182	0	....	....	2.92		Do.
	423	Aug. 14		35	....do	182	0	....	....	2.58		Do.
	424	Aug. 14		35	....do	182	0	....	....	2.58		Do.
	425	Aug. 14		35	....do	182	0	....	....	2.50		Do.
	426	Aug. 14		35	....do	182	0	....	....	2.58		Do.
	427	Aug. 14		35	....do	182	0	....	....	2.75		Do.
	428	Aug. 14		35	....do	182	0	....	....	2.58		Do.
	429	Aug. 14		35	....do	182	0	....	....	2.67		Do.
	430	Aug. 14		35	....do	180	0	....	....	2.75		Do.
	431	Aug. 14		35	....do	180	0	....	....	2.75		Do.
	432	Aug. 14		35	....do	180	0	....	....	2.25		Do.
	433	Aug. 14		35	....do	180	0	....	....	2.58		Do.
	434	Aug. 14		35	....do	180	0	....	....	2.67		Do.
	435	Aug. 14		35	....do	180	0	....	....	2.67		Do.
	436	Aug. 14		35	....do	180	0	....	....	2.75		Fired into sand butt. Upper bolt right-hand elevating trunnion broke—replaced.
	437	Aug. 14		35	....do	179	0	....	....	2.50		Fired into sand butt.
	438	Aug. 14		35	....do	170	0	....	....	2.67		Do.
	439	Aug. 14		35	....do	179	0	....	....	2.50		Do.
	440	Aug. 14		35	....do	179	0	....	....	2.58		Do.
	441	Aug. 14		35	....do	184	0	31,000	1,399	2.67		Do.
	442	Aug. 14		35	....do	184	0	....	....	2.58		Do.
	443	Aug. 14		35	....do	184	0	....	....	2.67		Do.
	444	Aug. 14		35	....do	184	0	....	....	2.67		Do.
	445	Aug. 14		35	....do	184	0	....	....	2.57		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch. of bore (Crusher).	Instrumental velocity, 109 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 30.149; thermometer, 73.4; humidity, 69.	446	Aug. 14	Du Pont's sphero-hexagonal K. H. C. Density, 1.775; granulation, 123.	35	Butler (re-saboted).	184	0			2.50	From front and left, 43°. 4 miles an hour.	Fired into sand butt.
	447	Aug. 14		35	do	184	0			2.50		Do.
	448	Aug. 14		35	do	184	0			2.92		Do.
	449	Aug. 14		35	do	178	0			2.50		Do.
	450	Aug. 14		35	do	178	0			2.57		Do.
	451	Aug. 14		35	do	178	0			2.75		Do.
	452	Aug. 14		35	do	178	0			2.50		Do.
	453	Aug. 14		35	do	178	0			2.42		Do.
	454	Aug. 14		35	do	178	0			2.25		Do.
	455	Aug. 14		35	do	178	0			2.33		Do.
	456	Aug. 14		35	do	178	0			2.16		Do.
	457	Aug. 14		35	do	178	0			2.50		Do.
	458	Aug. 14		35	do	178	0			2.25		Do.
	459	Aug. 14		35	do	179	0			2.50		Do.
	460	Aug. 14		35	do	179	0			2.50		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken.
Barometer, 30.041; thermometer, 85.4; humidity, 49.	461	Aug. 15		35	do	180	0	30,150	1,392	2.75	From rear and right, 87°; 3 miles an hour.	Fired into sand butt.
	462	Aug. 15		35	do	184	0			2.67		Do.
	463	Aug. 15		35	do	181	0			2.67		Do.
	464	Aug. 15		35	do	183	0			2.58		Do

Barometer, 30.041; thermometer, 85.4; humidity, 49.	465	Aug. 15	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 123.	35	....do	179	0			2.58	From rear and right, 87°; 3 miles an hour.	Do.
	466	Aug. 15		35	....do	181	0			2.67		Do.
	467	Aug. 15		35	....do	182	0			2.67		Do.
	468	Aug. 15		35	....do	181	0			2.50		Do.
	469	Aug. 15		35	....do	173	0			2.50		Do.
	470	Aug. 15		35	....do	177	0			2.67		Do.
	471	Aug. 15		35	....do	176	0			2.50		Do.
	472	Aug. 15		35	....do	180	0			2.75		Do.
	473	Aug. 15		35	....do	177	0			2.50		Do.
	474	Aug. 15		35	....do	177	0			2.67		Do.
	475	Aug. 15		35	....do	181	0			2.58		Do.
	476	Aug. 15		35	....do	180	0			2.67		Do.
	477	Aug. 15		35	....do	182	0			2.50		Do.
	478	Aug. 15		35	....do	178	0			2.67		Do.
	479	Aug. 15		35	....do	178	0			2.67		Do.
	480	Aug. 15		35	....do	180	0			2.75		Do.
	481	Aug. 15		35	....do	180	0			2.83		Do.
	482	Aug. 15		35	....do	177	0			2.67		Do.
	483	Aug. 15		35	....do	177	0			2.92		Do.
	484	Aug. 15		35	....do	181	0			2.75		Do.
	485	Aug. 15		35	....do	178	0			2.67		Do.
	486	Aug. 15		35	....do	181	0			2.50		Do.
	487	Aug. 15		35	....do	179	0			2.67		Do.
	488	Aug. 15		35	....do	180	0			2.58		Do.
	489	Aug. 15		35	....do	178	0			2.67		Do.
	490	Aug. 15		35	....do	180	0			2.50		Do.

Record of firing with 8-inch muzzle-loading rifle No. 1, muzzle insertion (steel tube), at Sandy Hook, N. J., &c.—Continued.

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Crusher).	Instrumental velocity, 100 feet from muzzle.	Recoil.	Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc, etc.
			Kind.	Weight.	Kind.	Weight.						
		1884.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*	*Feet.*		
Barometer, 30.041; thermometer, 85.4; humidity, 49.	491	Aug. 15	Du Pont's sphero-hexagonal K. H. C.; density, 1.775; granulation, 123.	35	Butler (re-saboted.)	182	0	....	....	2.75	From rear and right, 87; 3 miles an hour.	Fired into sand butt.
	492	Aug. 15		35	...do	180	0	....	....	2.67		Do.
	493	Aug. 15		35	...do	179	0	....	....	2.50		Do.
	494	Aug. 15		35	...do	180	0	....	....	2.75		Do.
	495	Aug. 15		35	.. do	183	0	....	....	2.67		Do.
	496	Aug. 15		35	.. do	181	0	....	....	2.75		Do.
	497	Aug. 15		35	...do	182	0	....	....	2.67		Do.
	498	Aug. 15		35	Butler (new).	183	0	....	....	2.92		Do.
	499	Aug. 15		35	.. do	183	0	....	....	2.67		Do.
	500	Aug. 15		35	... do	186	0	....	....	2.58		Fired into sand butt. Gun washed out, examined, star-gauged, and impressions taken after 500 rounds.

APPENDIX 22.

PROGRESS REPORT OF TRIALS OF A 3.2-INCH STEEL FIELD GUN BY THE BOARD FOR TESTING RIFLED CANNON, APPOINTED UNDER THE ACT OF JULY 5, 1884.

(1 plate.)

This gun was transferred by the Ordnance Board to the Board for Testing Rifled Cannon, &c., August 1, 1884, after it had been fired 60 rounds.

For a description of the gun the Board would refer to construction report from Watertown Arsenal and to Report No. 25 of the Ordnance Board for 1884.

The following summary of the first 60 rounds, giving mean pressure, velocity, &c., with 3½-pound charges, is taken from Ordnance Board report above referred to:

Initial velocity.	Pressure.	Energy.				
		Total.	Square inch of cross-section.	Per pound of powder.	Per pound weight of piece.	Per cent realized.
Feet.	*Pounds sq. inch.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons.*	*Foot-pounds.*	
*1,635	†29,116	241.20	29.99	68.91	681.33	78

* Mean of 18 rounds. † Mean of 25 rounds.

Since coming into the hands of this Board the gun has been fired 184 rounds, making a total of 244 rounds.

Of the 184 rounds 156 were fired into the sand butt, 2 were fired over water for exhibition in presence of Ordnance Committee of Congress, 1 was a sighting shot at mile target, and 25 at 1-inch mile target for accuracy.

This target was 20 by 40 feet, made of spruce boards 1 inch thick, and is hereto appended.

The results of firing for accuracy with 3.5-pound charges of I. K. D. powder with 13-pound projectiles were as follows for 25 rounds (75 to 99, inclusive):

	Feet.
Mean vertical deviation	3.63
Mean horizontal deviation	2.23
Mean deviation	4.26

For pressure and velocity with 3.5-pound charges and 13-pound projectiles:

Number of rounds.	Velocity 100 feet from muzzle.	Pressure per square inch.	Remarks.
Mean of 6 rounds	1,605	27,375	Using Freyre gas check.
Do	1,629	29,950	Using De Bange gas check.

One round (201st) was fired with 4.5 pounds K. V. powder (density 1.755; granulation 290), giving 1,712 feet velocity and 33,500 pounds pressure; one round (204th), fired with 3.5 pounds K. V. powder, gave 1,518 feet velocity and 25,400 pounds pressure. Another round (202d), fired with 3.25 pounds I. K. D. powder, gave 1,586 feet velocity and 29,100 pounds pressure.

The gun was star gauged after the 5th, 9th, 16th, 23d, 33d, and 60th rounds by the Ordnance Board, and after the 70th, 100th, 132d, 152d, 200th, and 244th rounds by this Board.

After the 100th round the Freyre gas check was reseated and slightly modified, from which time it acted perfectly, operating easily and preventing all escape of gas. The De Bange gas check prevented the escape of gas without failure, but from imperfect construction did not operate easily.

The firing records to include the 244th round, and the table of enlargements are appended hereto, forming part of this report.

The 3.2-inch steel gun has sustained the firing to the present time without any apparent injury or deterioration whatever.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

Table showing enlargement of bore and chamber of 3.2-inch breech-loading rifle (steel).

Inches from muzzle.	Original diameter of bore.	Diameter after 244 rounds.	Enlargement.	Inches from muzzle.	Original diameter of bore.	Diameter after 244 rounds.	Enlargement.
	Inches.	*Inches.*	*Inch.*		*Inches.*	*Inches.*	*Inch.*
70	3. 207	3. 215	0. 008	35	3. 205	3. 208	0. 003
69	3. 207	3. 215	. 008	34	3. 205	3. 208	. 003
68	3. 207	3. 215	. 008	33	3. 205	3. 208	. 003
67	3. 207	3. 214	. 007	32	3. 205	3. 208	. 003
66	3. 207	3. 214	. 007	31	3. 204	3. 208	. 004
65	3. 207	3. 213	. 006	30	3. 204	3. 208	. 004
64	3. 206	3. 213	. 007	29	3. 204	3. 208	. 004
63	3. 206	3. 212	. 006	28	3. 204	3. 208	. 004
62	3. 206	3. 211	. 005	27	3. 204	3. 208	. 004
61	3. 206	3. 211	. 005	26	3. 204	3. 207	. 003
60	3. 206	3. 211	. 005	25	3. 204	3. 207	. 003
59	3. 205	3. 211	. 006	24	3. 203	3. 207	. 004
58	3. 205	3. 211	. 006	23	3. 203	3. 207	. 004
57	3. 205	3. 210	. 005	22	3. 203	3. 207	. 004
56	3. 205	3. 210	. 005	21	3. 204	3. 206	. 002
55	3. 205	3. 210	. 005	20	3. 204	3. 206	. 002
54	3. 205	3. 209	. 004	19	3. 204	3. 206	. 002
53	3. 205	3. 210	. 005	18	3. 204	3. 206	. 002
52	3. 205	3. 209	. 004	17	3. 204	3. 206	. 002
51	3. 205	3. 209	. 004	16	3. 205	3. 206	. 001
50	3. 205	3. 210	. 005	15	3. 205	3. 206	. 001
49	3. 205	3 210	. 005	14	3. 205	3. 206	. 001
48	3. 205	3. 209	. 004	13	3. 205	3. 206	. 001
47	3. 205	3. 209	. 004	12	3. 205	3. 206	. 001
46	3. 205	3. 209	. 004	11	3. 205	3. 206	. 001
45	3. 205	3. 209	. 004	10	3. 205	3. 206	. 001
44	3. 205	3. 209	. 004	9	3. 205	3. 207	. 002
43	3. 205	3. 209	. 004	8	3. 205	3. 207	. 002
42	3. 205	3. 209	. 004	7	3. 205	3. 207	. 002
41	3. 205	3. 209	. 004	6	3. 207	3. 208	. 001
40	3. 205	3. 209	. 004	5	3. 207	3. 208	. 001
39	3. 205	3. 209	. 004	4	3. 208	3. 208	. 000
38	3. 205	3. 209	. 004	3	3. 208	3. 208	. 000
37	3. 205	3. 209	. 004	2	3. 207	3. 208	. 001
36	3. 205	3. 209	. 004	1	3. 207	3. 208	. 001

POWDER CHAMBER.

Inches from breech.	Original diameter.	Diameter after 244 rounds.	Enlargement.
	Inches.	*Inches.*	*Inch.*
11. 2	3. 768	3. 772	0. 004
13. 2	3. 81	3. 814	. 004
15. 2	3. 755	3. 726	—. 029

Record of firing with 3.2-inch breech-loading rifle (steel)

	Number of fire.	Time.	Powder.			Projectile.				Elevation.		Pressure, per square inch of bore, crusher.	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.		Wgt Pounds.	Wgt Ounces.						
		1884.								°	'	*Lbs.*	*Feet.*	*Feet.*	
Barometer, 30.028; thermometer, 79.8; humidity, 55.	61	Aug. 1	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell (ressaboted). Band, 3''.30 diameter, 0''.5 wide; beveled front and rear.		13	..		0	......	......	9.83	From front and right, 48°; 10 miles an hour.
	62	Aug. 1		3	8			13	..		0	......	......	9.33	
	63	Aug. 1		3	8			13	..		0	....	......	9.83	
	64	Aug. 1		3	8			13	..		0	......	....	9.16	
	65	Aug. 1		3	8			13	..		0	......	......	9.16	
	66	Aug. 1		3	8			13	..		0	......	......	9.25	
	67	Aug. 1		3	8			13	..		0	......	......	9.50	
	68	Aug. 1		3	8			13	..		0	......	......	9.66	
	69	Aug. 1		3	8			13	..		0	......	......	9.33	
	70	Aug. 1		3	8			13	..		0	......	.....	9.66	
Barometer, 30.258; thermometer, 71; humidity, 72.	71	Aug. 9		3	8	Solid band experimental shell. Band, 3''.30, 0''.5 wide; beveled front and rear.	Old.	13	..		0	28,000	1,621	9.33	10 miles an hour. From front and left, 87°.
	72	Aug. 9		3	8			13	..		8	......	......	8.00	From front and left, 20°.
	73	Aug. 9		3	8			13	..		8	......	......	8.50	
Barometer, 30.041; thermometer, 85.4; humidity, 49.	74	Aug. 15		3	8		New.	13	..	2	30	......	......	8.00	....
	75	Aug. 15		3	8			13	..	2	25	......	......	8.00	From rear and right, 43°; 4 miles an hour.
	76	Aug. 15		3	8			13	..	2	25	......	......	8.08	
	77	Aug. 15		3	8			13	..	2	25	......	.....	8.83	
	78	Aug. 15		3	8			13	..	2	25	......	.....	8.25	
	79	Aug. 15		3	8			13	..	2	25	......	.....	8.25	
	80	Aug. 15		3	8			13	..	2	25	.....	......	8.50	
	81	Aug. 15		3	8			13	..	2	25	......	.....	8.33	
	82	Aug. 15		3	8			13	..	2	25	....	.....	8.50	
	83	Aug. 15		3	8			13	..	2	25	......	.....	8.33	
	84	Aug. 15		3	8			13	..	2	25	......	......	8.25	
	85	Aug. 15		3	8			13	..	2	25	......	......	8.25	
	86	Aug. 15		3	8			13	..	2	25	......	.....	8.33	
	87	Aug. 15		3	8			13	..	2	25	......	......	8.16	

at Sandy Hook, N. J., from August 1 to October 2, 1884.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.

New steel obturator and ring put in before round 61.

Slight escape of gas. Gun opened easily.

Gun opened less easily.

Gun opened easily.

Gun opened less easily.

Fired into sand butt. No escape of gas. Gun opened easily.

Gun closed easily during these rounds and seemed to open more easily as the firing progressed.

Fired into sand butt.

Fired over water. (Time of flight, 12½ seconds.) Good flight.

Fired over water. (Time of flight, 13 seconds.) Good flight.

Fired for exhibition in presence of the Ordnance Committee. No escape of gas. Opened and closed easily.

Fired at mile target. Sighting shot. Good flight.

Distance from center of target, in feet.				Distance from center of impact, in feet.			
Vertical.		Horizontal.		Vertical.		Horizontal.	
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.
....	0.50	....	4.50	1.49	....	2.78	....
8.00	....	....	4.50	9.99	....	2.78	....
....	8.00	....	4.75	....	6.01	2.53	....
4.00	....	....	6.00	5.99	....	1.28	....
0.75	....	....	6.00	2.74	....	1.28	....
....	2.00	....	7.00	....	0.01	0.28	....
....	6.00	....	6.00	....	4.01	1.28	....
....	5.75	....	6.25	....	3.76	1.03	....
7.00	....	....	7.50	8.99	....	....	0.22
4.00	....	....	8.25	5.99	....	....	0.97
....	0.50	....	8.00	1.49	....	....	0.72
....	0.75	....	8.00	1.24	....	....	0.72
....	1.50	....	8.25	0.49	....	....	0.97

Fired at mile target. Target, 20' by 40', made of 1" spruce boards. With exception of one round, gun opened and closed easily and there was no escape of gas.

Good flight.

Record of firing with 3.2-inch breech-loading rifle (steel),

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore, crusher.	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt Pounds.	Wgt Ounces.	Kind.	Wgt Pounds.	Wgt Ounces.					
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
Barometer, 30.041; thermometer, 85.4; humidity, 49.	88	Aug. 15	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell. Band, 3″.30, 0″.5 wide; beveled front and rear. New.	13	..	2 25	......	......	8.50	From rear and right, 43°; 4 miles an hour.
	89	Aug. 15		3	8		13	..	2 25	......	......	9.16	
	90	Aug. 15		3	8		13	..	2 25	......	......	9.00	
	91	Aug. 15		3	8		13	..	2 25	......	......	8.67	
	92	Aug. 15		3	8		13	..	2 25	......	......	9.50	
	93	Aug. 15		3	8		13	..	2 25	....	......	8.50	
	94	Aug. 15		3	8		13	..	2 25	....	......	9.00	
	95	Aug. 15		3	8		13	..	2 25	......	......	9.00	
	96	Aug. 15		3	8		13	..	2 25	......	......	9.00	
	97	Aug. 15		3	8		13	..	2 25	......	......	9.00	
	98	Aug. 15		3	8		13	..	2 25	......	......	8.50	
	99	Aug. 15		3	8		13	..	2 25	......	......	8.83	
	100	Aug. 15		3	8		13	..	0	29,950	1,618	9.75	
Barometer, 29.899; thermometer, 80.2; humidity, 44.	101	Sept. 16		3	8	Solid band experimental shell; band 3″.30 diameter, 0″.5 wide; beveled front and rear. Old.	13	..	—¼	......	......	9.50	From front and right, 48°; 26 miles an hour.
	102	Sept. 16		3	8		13	..	—¼	......	......	23.00	
Barometer, 29.827; thermometer, 77.8; humidity, 63.	103	Sept. 17		3	—		13	..	—¼	......	......	8.50	From rear and right, 87°; 11 miles an hour.
	104	Sept. 17		3	8		13	..	—¼	......	......	9.50	
	105	Sept. 17		3	8		13	..	—¼	......	......	9.50	
	106	Sept. 17		3	8		13	..	—¼	......	......	9.50	
	107	Sept. 17		3	8		13	..	—¼	......	......	9.75	
	108	Sept. 17		3	8		13	..	—¼	......	......	9.75	
	109	Sept. 17		3	8		13	..	—¼	......	......	9.50	
	110	Sept. 17		3	8		13	..	—¼	......	......	9.00	
	111	Sept. 17		4	8		13	..	—¼	......	......	9.25	
	112	Sept. 17		3	8		13	..	—¼	......	.....	9.25	

at Sandy Hook, N. J., from August 1 *to October* 2, 1884—Continued.

Distance from center of target, in feet.				Distance from center of impact, in feet.				Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.	
Vertical.		Horizontal.		Vertical.		Horizontal.			
Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.		
....	6.00	....	7.75	....	4.01	....	0.47	Fired at mile target. Target, 20' by 40', made of 1" spruce boards. With exception of one round, gun opened and closed easily and there was no escape of gas.	Good flight.
....	5.75	....	10.25	....	3.76	....	2.97		
....	8.25	....	9.75	....	6.26	....	2.47		
1.50	....	....	1.00	3.49	....	6.28	....		
....	0.25	....	3.00	1.74	....	4.28	....		
....	0.25	....	4.00	1.74	....	3.28	....		
....	2.00	....	9.25	....	0.01	....	1.97		
....	6.00	....	10.00	....	4.01	....	2.72		
....	4.00	....	12.00	....	2.01	....	4.72		
....	3.50	....	15.00	....	1.51	....	7.72		
....	6.00	....	8.50	....	4.01	....	1.22		
....	8.00	....	6.50	....	6.01	0.78	....		
25.25	75.00	....	182.00	45.38	45.38	27.86	27.86	Mean vertical deviation from center of impact, 3'.63. Mean horizontal deviation from center of impact, 2'.23.	
49.75÷25=1.99		182÷25=7.28		90.76÷25=3.63		55.72÷25=2.23		Mean deviation from center of impact, 4'.26.	

Fired into butt. Gun washed out, examined, star gauged after 70th and 100th rounds.

Fired into sand butt. Gun closed and opened easily, with no escape of gas.

Brakes not on.

Fired to prove gas check, which had been reseated by Mr. Allen, from Watertown Arsenal.

Record of firing with 3.2-inch breech-loading rifle (steel)

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore, crusher.	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength, and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M. Barometer, 30.071; thermometer, 67; humidity, 84.	113	Sept. 23	Du Pont's I. K. L.; density 1.725; granulation 2,200.	3	8	Solid band experimental shell; band 3.30″ diameter, 0.5″ wide; beveled front and rear. New.	13	..	—¼	27,100	1,608	9.50	From front and left, 87°; 15 miles an hour.
	114	Sept. 23		3	8		13	..	—¼	......	......	9.50	
	115	Sept. 23		3	8		13	..	—¼	......	......	10.00	
	116	Sept. 23		3	8		13	..	—¼	......	......	9.50	
	117	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	118	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	119	Sept. 23		3	8		13	..	—¼	......	......	9.50	
	120	Sept. 23		3	8		13	..	—¼	......	......	9.00	
	121	Sept. 23		3	8		13	..	—¼	......	......	10.00	
	122	Sept. 23		3	8		13	..	—¼	......	......	10.00	
	123	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	124	Sept. 23		3	8		13	..	—¼	......	......	10.00	
	125	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	126	Sept. 23		3	8		13	..	—¼	......	......	9.00	
	127	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	128	Sept. 23		3	8		13	..	—¼	......	......	9.50	
	129	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	130	Sept. 23		3	8		13	..	—¼	......	......	9.50	
	131	Sept. 23		3	8		13	..	—¼	......	......	9.25	
	132	Sept. 23		3	8		13	..	—¼	......	......	9.50	
A. M. Barometer, 30.155; thermometer, 68.1; humidity, 88.	133	Sept. 24		3	8		13	..	—¼	26,300	1,598	9.50	From rear and right, 87°; 10 miles an hour.
	134	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	135	Sept. 24		3	8		13	..	—¼	......	......	10.00	
	136	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	137	Sept. 24		3	8		13	..	—¼	......	......	9.33	
	138	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	139	Sept. 24		3	8		13	..	—¼	......	......	9.42	
	140	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	141	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	142	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	143	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	144	Sept. 24		3	8		13	..	—¼	......	......	9.00	
	145	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	146	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	147	Sept. 24		3	8		13	..	—¼	......	......	9.33	
	148	Sept. 24		3	8		13	..	—¼	......	......	9.50	

at Sandy Hook, N. J., from August 1 *to October* 2, 1884—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Fired into sand butt Gun closed and opened easily, with no escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel),

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore-crusher.	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt.		Kind.	Wgt.						
				Pounds.	Ounces.		Pounds.	Ounces.					
		1884.							° '	*Lbs.*	*Feet.*	*Feet.*	
A.M.—Barometer, 30.155; thermometer, 68.1; humidity, 88.	149	Sept. 24	Du Pont's I. K. D. Density, 1.725. Granulation, 2200.	3	8	Solid band experimental shell. Band, 3''. diameter; 0''.5 wide. Beveled front and rear. New.	13	..	—½	......	......	9.33	From rear and right, 87°; 10 miles an hour.
	150	Sept. 24		3	8		13	..	—½	......	......	9.25	
	151	Sept. 24		3	8		13	..	—½	......	......	9.33	
	152	Sept. 24		3	8		13	..	—½	......	......	9.33	
A. M.—Barometer 30.129; thermometer, 80.8; humidity, 60.	153	Sept. 24		3	8		13	..	—½	25,400	1,588	9.00	From front and right, 48°; 14 miles an hour.
	154	Sept. 24		3	8		13	..	—½	......	......	9.00	
	155	Sept. 24		3	8		13	..	—½	......	......	9.08	
	156	Sept. 24		3	8		13	..	—½	......	......	9.42	
	157	Sept. 24		3	8		13	..	—½	......	......	9.16	
	158	Sept. 24		3	8		13	..	—½	......	......	9.50	
	159	Sept. 24		3	8		13		—½	......	......	9.00	
	160	Sept. 24		3	8		13	..	—½	......	......	9.16	
	161	Sept. 24		3	8		13	..	—½	......	......	9.16	
	162	Sept. 24		3	8		13	..	—½	......	......	9.33	
	163	Sept. 24		3	8		13	..	—½	......	......	9.00	
	164	Sept. 24		3	8		13	..	—½	......	......	9.33	
	165	Sept. 24		3	8		13	..	—½	......	......	9.16	
	166	Sept. 24		3	8		13	..	—½	......	......	9.00	
	167	Sept. 24		3	8		13	..	—½	......	......	9.50	
	168	Sept. 24		3	8		13	..	—½	......	......	9.33	
	169	Sept. 24		3	8		13	..	—½	......	......	9.50	
	170	Sept. 24		3	8		13	..	—½	......	......	9.33	
	171	Sept. 24		3	8		13	..	—½	......	......	9.33	
	172	Sept. 24		3	8		13	..	—½	......	......	9.33	
P.M.—Barometer, 30.096; thermometer, 77.4; humidity, 68.	173	Sept. 24		3	8		13	..	—½	......	......	9.00	Front and right, 3°; 24 miles an hour.
	174	Sept. 24		3	8		13	..	—½	......	......	9.33	
	175	Sept. 24		3	8		13	..	—½	......	......	10.00	
	176	Sept. 24		3	8		13	..	—½	......	......	9.50	
	177	Sept. 24		3	8		13	..	—½	......	......	9.67	
	178	Sept. 24		3	8		13	..	—½	......	......	9.25	
	179	Sept. 24		3	8		13	..	—½	......	......	9.00	
	180	Sept. 24		3	8		13	..	—½	......	......	9.75	
	181	Sept. 24		3	8		13		—½	......	......	9.25	
	182	Sept. 24		3	8		13	..	—½	......	......	10.00	
	183	Sept. 24		3	8		13	..	—½	......	......	9.75	
	184	Sept. 24		3	8		13	..	—½	......	......	9.25	

at Sandy Hook, N. J., from August 1 *to October* 2, 1884—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Fired into sand-butt. Gun closed and opened easily, with no escape of gas.
Gun washed out, examined, and star-gauged after 132d and 152d rounds.
Fired into sand butt. Gun closed and opened easily; no escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel),

	Number of fire.	Time.	Powder. Kind.	Powder. Wgt. Pounds.	Powder. Wgt. Ounces.	Projectile. Kind.	Projectile. Wgt. Pounds.	Projectile. Wgt. Ounces.	Elevation.	Pressure, per square inch of bore. Crusher.	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.096; thermometer, 77.4; humidity, 68.	185	Sept. 24	Du Pont's I. K. D. Density, 1.725. Granulation, 2200.	3	8	Solid band experimental shell. Band, 3″.30; diameter, 0″.5 wide. Beveled front and rear. New.	13	..	—¼	......	......	9.50	Front and right, 3°; 24 miles an hour.
	186	Sept. 24		3	8		13	..	—¼	....	.....	9.50	
	187	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	188	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	189	Sept. 24		3	8		13	..	—¼	......	......	9.25	
	190	Sept. 24		3	8		13	..	—¼	......	......	10.00	
	191	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	192	Sept. 24		3	8		13		—¼	....	......	9.75	
	193	Sept. 24		3	8		13	..	—¼	.....	...	9.75	
	194	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	195	Sept. 24		3	8		13	..	—¼	......	......	9.75	
	196	Sept. 24		3	8		13	..	—¼	......	......	9.50	
	197	Sept. 24		3	8		13	..	—¼	......	......	10.00	
	198	Sept. 24		3	8		13	..	—¼	....	......	9.50	
	199	Sept. 24		3	8		18	..	—¼	......	......	9.50	
	200	Sept. 24		3	8		13	..	—¼	27,500	1,597	9.50	
P. M.—Barometer 30.388; thermometer, 69.4; humidity, 56.	201	Sept. 26	Du Pont's K. V. Density, 1.755. Granulation, 200.	4	8	Solid band experimental shell. Band, 3″.30; diameter, 0″.5 wide. Beveled front and rear. Old.	13	..	—¼	33,500	1,712	10.50	From front and left, 87°. 18 miles an hour.
Barometer, 30.173; thermometer, 68.7; humidity, 68.	202	Sept. 27	I. K. D.	3	4		13	..	—¼	29,100	1,586	7.50	22 miles an hour.
	203	Sept. 27		3	8		13	..	—¼	31,000	1,627	9.00	
	204	Sept. 27	K. V.	3	8		13	..	—¼	25,400	1,518	8.75	
P. M.—Barometer, 30.152; thermometer, 70.4; humidity, 74.	205	Sept. 30	Du Pont's I. K. D. Density, 1.725; granulation, 2,200.	3	8	Solid band experimental shell. Band; 3″.30 diameter; 0″5 wide. Beveled front and rear. New.	13	..	—¼	31,500	1,648	8.33	From front; 6 miles an hour.
	206	Sept. 30		3	8		13	..	—¼	30,100	1,629	8.50	
	207	Sept. 30		3	8		13	..	—¼	29,700	1,639	9.00	
	208	Sept. 30		3	8		13	..	—¼	30,300	1,632	9.16	
	209	Sept. 30		3	8		13	..	—¼	27,100	1,598	8.83	
	210	Sept. 30		3	8		13	..	—¼	......	....	11.00	
	211	Sept. 30		3	8		13	..	—¼	......	......	12.50	
	212	Sept. 30		3	8		13	..	—¼	......	......	12.00	
	213	Sept. 30		3	8		13	..	—¼	.....	......	12.00	
	214	Sept. 30		8	8		13	..	—¼	......	......	12.00	

at Sandy Hook, N. J., from August 1 *to October* 2, 1884—Continued.

	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc, etc.
Fired into sand butt.	Gun closed and opened easily; no escape of gas.
	Gun star gauged after 200th round.
	De Bange gas-check. Closed and opened easily with no escape of gas, excepting round 204, when gun opened little hard.
De Bange gas-check. Fired into sand butt.	Closed and opened easily; no escape of gas.
	Do.
	Gun closed easily but opened a little hard; no escape of gas.
	Gun closed and opened a little hard; no escape of gas.

Record of firing with 3.2-inch breech-loading rifle (steel)

	Number of fire.	Time.	Powder.			Projectile.			Elevation.	Pressure, per square inch of bore. Crusher	Instrumental velocity 100 feet from muzzle.	Recoil.	Wind, strength and direction.
			Kind.	Wgt.		Kind.	Wgt.						
				Pounds.	Ounces.		Pounds.	Ounces.					
		1884.							° ′	*Lbs.*	*Feet.*	*Feet.*	
P. M.—Barometer, 30.152; thermometer, 70.4; humidity, 74.	215	Sept. 30	Du Pont's I. K. D. Density, 1.725; granulation, 2200.	3	8	Solid band experimental shell. Band 3".30 diameter; 0".5 wide. Beveled front and rear. New.	13	..	−¼	......	....	12.50	From front; 6 miles an hour.
	216	Sept. 30		3	8		13		−¼	......	......	15.00	
	217	Sept. 30		3	8		13	..	−¼	......	......	15.00	
	218	Sept. 30		3	8		13		−¼	......	......	15.00	
	219	Sept. 30		3	8		13	..	−¼	......	......	14.00	
	220	Sept. 30		3	8		13	..	−¼	......	......	14.00	
	221	Sept. 30		3	8		13	..	−¼	......	......	15.00	
	222	Sept. 30		3	8		13	..	−¼	......	......	16.00	
	223	Sept. 30		3	8		13		−¼	......	......	14.00	
	224	Sept. 30		3	8		13	..	−¼	....	......	12.00	
	225	Sept. 30		3	8		13		−¼	......	......	12.00	
	226	Sept. 30		3	8		13	..	−¼	......	......	11.00	
	227	Sept. 30		3	8		13	..	−¼	......	......	12.00	
	228	Sept. 30		3	8		13	..	−¼	......	......	10.75	
	229	Sept. 30		3	8		13	..	−¼	....	......	11.00	
	230	Sept. 30		3	8		13	..	−¼	......	....	11.00	
	231	Sept. 30		3	8		13	..	−¼	......	......	10.75	
	232	Sept. 30		3	8		13	..	−¼	......	...	10.75	
	233	Sept. 30		3	8		13	..	−¼	......	......	10.75	
P. M.—Barometer, 30.147; thermometer, 80.3; humidity, 60.	234	Oct. 1		3	8		13	.	−¼	......	......	40.00	From rear and right, 43°; 2 miles an hour.
P. M.—Barometer, 30.329; thermometer, 56.1; humidity, 90.	235	Oct. 2		3	8		13	..	−¼	......	......	16.50	From rear and left, 48°; 27 miles an hour.
	236	Oct. 2		3	8		13	..	−¼	......	......	9.75	
	237	Oct. 2		3	8		13	..	−¼	......	......	12.25	
	238	Oct. 2		3	8		13	..	−¼	......	......	12.50	
	239	Oct. 2		3	8		13	..	−¼	......	......	12.67	
	240	Oct. 2		3	8		13	..	−¼	......	......	12.50	
	241	Oct. 2		3	8		13		−¼	......	......	10.67	
	242	Oct. 2		3	8		13	..	−¼	......	......	11.50	
	243	Oct. 2		3	8		13	..	−¼	......	......	10.50	
	244	Oct. 2		3	8		13	..	−¼	......	......	12.50	

at Sandy Hook, N J., from August 1 to October 21, 1884—Continued.

Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
De Bange gas-check. Fired into sand-butt.
Gun closed and opened a little hard; no escape of gas.
Hasp on trail chest broke off.
Angle iron of right cheek of carriage broken and right cheek commencing to buckle at middle transom.
Gun mounted on 12-pounder field carriage.
Gun closed a little hard; opened easily. No escape of gas.
No brakes on carriage.
Brakes on carriage.
Right brake jumped off.

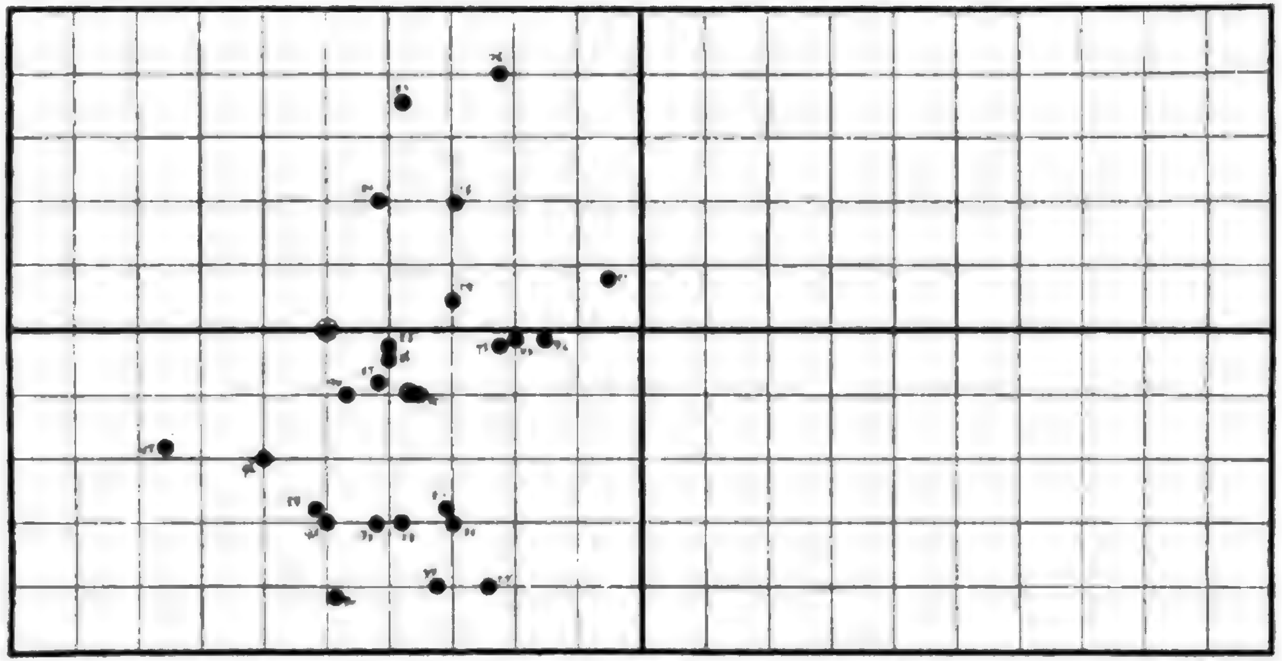
PLATE I.

TARGET RECORD of 3.2 B.L. Rifle (Steel)

August [illegible] AT SANDY HOOK, N. J.

Target One mile *from Gun.*

Number of shots fired. 25 *Direct hits.* 25 *Ricochet hits* 0 *Misses.* 0



● *Center of impact.*

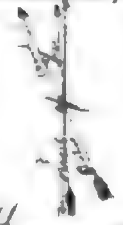
● *Point aimed at.*

Target 10' × 10'

Mean vertical deviation from center of impact. 3.63

Mean horizontal deviation from center of impact. 2.23

Mean deviation from center of impact. 4.31



Wind 4 *miles per hour.*

Appendix 22—1884.

Appendix 23.

TRIAL OF H. F. MANN'S 6½-INCH BREECH-LOADING RIFLED CANNON, BY THE BOARD FOR TESTING RIFLED CANNON, APPOINTED UNDER ACT OF JULY 5, 1884.

(5 plates.)

This rifle was transferred to the Board for testing by Ordnance Office letter of July 31, 1884.

For detailed description and dimensions of the gun the Board would refer to the construction and inspection reports made by the inspector of ordnance, U. S. A., at Boston, Mass.

The gun is converted from a 10-inch Rodman smooth-bore gun by lining with a steel tube and shrinking on a steel jacket. The breech mechanism consists essentially of a cast-iron breech-block, held in position by a transom, breech-screw, and side straps, for transmitting the pressure to the trunnions. The tube, jacket, breech-screw, transom, and side straps are all of Whitworth steel.

A drawing of the gun is given in Plate I.

Two photographs are inclosed with the report, one giving a view of the Mann gun just after rupture, and the other a view of the fractured pieces.

CARRIAGE.

The carriage needs no special mention, as it was originally a 15-inch gun-carriage altered for the multicharge gun, and later adapted for use with the 6.5-inch Mann breech-loading rifle.

PROJECTILES.

These were made under contract with the department at Pittsburgh, Pa., from the design and under the direction of Mr. Mann. There were three kinds of these projectiles, classified according to the banding. Each projectile has two composition bands upon the cylindrical body—one in front, and the other in rear of the center of gravity, cast into double dovetailed grooves and then turned to proper size.

CLASSIFICATION, ETC.

	No. of projectiles.
No. 1, marked 1 on base	172
No. 2, marked 2 on base	24
No. 3, marked 3 on base	54
Total number of projectiles	250

COMPOSITION OF BANDS.

	Per cent.
No. 1. Composition of alloy:	
Lead	65.4
Tin	33.0
Copper	1.6

No. 2. Composition of alloy unknown. It was given by Mr. Mann as Mansfield & Co.'s "A 1" Babbitt metal.

	Per cent.
No. 3. Composition of alloy:	
Lead	75
Tin	15
Copper	2.5
Antimony	7.5

These projectiles are all of the same form, cylindro-ogival, and about the same weight, all coming within the inspection limits.

COPPER BANDS.

After the 12th round a solid copper band was substituted for the rear band of soft alloy.

For five rounds (15th to 19th, both inclusive) a V-shaped groove was turned in the copper band; for the 20th round a trapezoidal groove was substituted, and for the 21st the same groove, with the addition of a bevel on the rear of the band. The deep trapezoidal groove was employed in the last three rounds. In all the copper-banded projectiles the front band of composition metal was turned down even with the surface of the shot.

POWDER.

Twenty-three rounds (Nos. 1 to 23, both inclusive) were fired with Du Pont's "I. C." sphero-hexagonal powder, density = 1.815 and granulation 123. The 24th and last round was fired with Du Pont's "K. H. C." sphero-hexagonal powder, density = 1.775, granulation 123.

GAS-CHECK.

There were *three* kinds of gas-checks submitted with the gun, the form being the same in all:

	Number.
No. 1, made of "Butler sabot metal," unmarked	10
No. 2, made of phosphor bronze, marked "B"	5
No. 3, made of phosphor bronze, marked "E"	5
Total	20

The form and dimensions of the gas-check are shown in Plate II.

EXPERIMENTS.

These were conducted at the Ordnance Proving Grounds at Sandy Hook, N. J.

RESULTS OF FIRING.

The details of the firing will be found in the firing record, table of enlargements of bore, and of chamber between 8th and 24th rounds, appended, and forming part of this report.

The following table, I, shows the pressures and velocities obtained with the different charges and kinds of powder, together with the different weights of projectiles:

I.—*Table showing kinds and weights of powder, projectiles, velocities, and pressures obtained in firing the 6.5-inch Mann B. L. rifle.*

No. of round.	Powder.		Mann projectile, 6.5-inch.		Instrumental velocity.		Pressure per square inch.		Gas-check.
	Kind.	Weight	Kind.	Weight	Observed mean at 108 feet 9 inches from muzzle.	Mean.	Observed.	Mean.	
		Pounds.		*Pounds.*	*Feet.*	*Feet.*	*Pounds.*	*Pounds.*	
1	L. C ...	20	No. 1	109	1, 106	....	7, 500	7, 750	Butler No. 1. Same gas-check used throughout.
2	L. C ...	20	No. 1......	109	Lost.	....	8, 000		
3	L. C...	25	No. 1......	109	1, 344	1, 347. 5	10, 500	11, 250	Do.
4	L. C...	25	No. 1......	109	1, 351		12, 000		
5	L. C...	30	No. 1......	109	1, 534	1, 516	17, 750	16, 625	Do.
6	L. C ..	30	No. 1......	109	1, 498		15, 500		
7	L. C...	35	No. 1......	109	1, 676	1, 653	24, 500	23, 750	Do.
8	L. C...	35	No. 1......	109	1, 630		23, 000		
9	L. C...	35	No. 2......	109	1, 637	1, 648. 5	26, 250	25, 125	Do.
10	L. C...	35	No. 2	109	1, 660		24, 000		
11	L. C...	35	No. 3......	109	1, 630	1, 629	23, 750	23, 625	Do.
12	L. C...	35	No. 3......	109	1, 628		23, 500		
					104′ 8″				
13	L. C ...	37	Solid copper band.	109	1, 747	1, 731. 5	26, 500	26, 875	Butler sabot metal No. 1.
14	L. C...	37	....do. ...	109	1, 716		27, 250		
					104′ 1″				
15	L. C...	37	V-grooved.	109	1, 737	1, 716. 6	26, 250	23, 300	Do.
16	L. C...	37	....do	109	1, 720		23, 250		
17	L. C...	37	.. do	109	1, 711		21, 500		
18	L. C...	37	... do	109	1, 707		22, 500		
19	L. C...	37	....do	109	1, 708		23, 000		
					104′ 4″				
20	L. C ..	37	Trapezoidal	109	1, 729	1, 722	25, 250	24, 750	Do.
21	L. C...	37	Trapezoidal and bevel.	109	1, 715		24, 250		
22	L. C ...	40	Trapezoidal	109	1, 735	1, 735. 5	27, 500	26, 250	Do.
23	L. C ..	40	... do	109	1, 736		25, 000		
24	K.H.C.	37	....do	109	1, 748	....	Lost.	....	Butler sabot metal No. 1; gun disabled.

SUMMARY OF EXPERIMENTS.

On consultation with Mr. Mann the Board determined upon a preliminary programme given below, which was submitted to Mr. Mann and approved by him.

Schedule (using No. 1 projectiles and Butler metal gas-check).

☞Gun to be fired two rounds with each of the following charges of powder, viz, 20, 25, 30, and 35 pounds L. C. sphero-hexagonal, the programme to be modified at any time if deemed necessary.

The above eight rounds were fired, the gun washed and star-gauged. The soft composition bands having stripped and failed to give proper rotation of the shot, it was decided to try two rounds each with Nos. 2 and 3 projectiles, using 35-pound charges of the same powder, to see if their bands would produce proper rotation. This programme being submitted to Mr. Mann and being agreed to by him, the shots were fired, and showed the same defects as No. 1.

After consultation with Mr. Mann, and with his assent and approval, the Board decided to substitute solid copper bands for the composition metal; the rear bands were then replaced by solid copper bands, the forward bands being turned off flush with the surface of the projectile, some of these having a central groove cut in them, as suggested by Mr. Mann.

The pressures obtained with the 35-pound charges being deemed too low to properly test the mechanism, the Board, with the approval of Mr. Mann, decided to use 37-pound charges with the solid copper-banded projectiles.

Two rounds (13th and 14th) were fired with this charge.

There being a considerable flow of copper to the rear the Board then continued the firing with the same charge, using the central groove suggested by Mr. Mann. The grooved band showed little advantage over the solid bands without groove, but its use was continued to the end of the firing.

The removal of the forward band, after the substitution of the copper rear band, permitted the projectile to be inserted further into the bore, increasing the powder-chamber so as to admit a charge of about 41.5 pounds of powder.

The pressures being still very low, upon consulting Mr. Mann he assented to the proposition to use 40 pounds of L. C. powder. Two rounds were fired with this charge. The velocities and pressure obtained did not differ materially from those obtained with 37 pounds, being slightly greater; and as a considerable quantity of powder was blown out unconsumed it was decided, with Mr. Mann's assent, to change the powder, and to return to a 37-pound charge, at least for the first few rounds.

The Board selected Du Pont's K. H. C. sphero-hexagonal powder, density 1.775, granulation 123, as one that had been fully tested in the 8-inch M. L. gun, steel lined M. I., and had been found to give fair velocities with moderate pressures, the latter having averaged from 29,000 to 32,000 pounds per square inch with a minimum of 26,650 and a maximum of 34,400 for 35-pound charges, using projectiles of about 180 pounds weight without air space between projectile and cartridge.

The 24th round was fired with 37 pounds of this (K. H. C.) powder and a 109-pound projectile, and an air space of 3.5-inch besides, the air space due to the differences in diameter of the chamber and cartridge.

At this round the breech transom of Whitworth steel was fractured about 3 inches from the left tenon, and was blown 54 feet to the rear, passing through a heavy wooden screen. The cast-iron breech-block was broken into three large and several smaller fragments, one of the large pieces being projected about 200 yards to the left and rear. The side straps were spread apart, but these straps and the main body of the gun appear to be uninjured.

The velocity obtained in this round was 1,748 feet, being about the same as that previously obtained. The pressure was lost owing to the destruction of the pressure-gauge at the time of rupture, but from the data previously obtained and the velocity record it is not probable that it greatly exceeded the pressures of preceding rounds.

The opening and closing of the breech mechanism was easily performed by two men after attaching a weight to the muzzle to counterpoise the breech preponderance of the gun-body on the loading trunnions.

The gas-check operated easily, being usually withdrawn by hand, though the tongs were resorted to in some instances. It was found that a wire edge requiring removal was thrown up around the exterior of the gas-check after nearly every round subsequent to the first few fired with the device. A light escape of gas between the gun and breech block was noted at times during the experiments. After the 18th round gas escaped through both vents, though one was bored only to the bushing.

The enlargements of the bore from the muzzle to within 41 inches of the breech are from 0 to 0.001 inch, being very slight indeed. The enlargement of the bore for 6 inches in front of the chamber is about 0.003 inch, and that of the chamber, as determined from star-gaugings made after the 8th and 24th rounds, was about 0.003 inch, except at 5 inches from the breech it increased to 0.005 inch, and varied uniformly from that to 0,008 inch at 2 inches from breech. The chamber was not star-gauged at the begining from lack of proper sized points for star-gauge.

It was observed in the course of the firing that the gun showed a slight vertical displacement, by reason of which the face of the breech was a little higher after than before firing. This indicated that at some period during the discharge, probably at the time of maximum pressure, the contact between the face of the breech and the movable cast-iron breech-block momentarily ceased.

A sketch giving the position of the fragments of the breech mechanism relative to the gun is shown in Plate III.

Plate IV shows the fracture of the Whitworth steel breech transom.

Plate V shows the fracture of the cast-iron breech-block.

This gun having burst at the 24th round, its endurance was not satisfactory to the Board, and hence it cannot recommend that it be "put to use in the Government service."

In the opinion of the Board the system was weak in some of its parts, notably the cast-iron breech-block. It is considered probable that the yielding of the breech-closing system, composed of the side-straps, transom, breech-block, and screw, permitted escape of the gas between the breech-block and the base of the gun, thus allowing the gas to exert its pressure upon a larger area of the breech-block than a cross section of the bore. This it is believed may have been the cause of the rupture, but there may have been some flaw or defect in the material of the breech-block or transom, although none could be detected by the eye.

T. G. BAYLOR,
Colonel of Ordnance, President of the Board.
F. H. PARKER,
Major of Ordnance.
GEO. W. McKEE,
Major of Ordnance.
CHARLES SHALER,
Captain of Ordnance.
D. A. LYLE,
Captain of Ordnance.

Table showing enlargement of bore and chamber of 6.5-inch breech-loading rifle (Mann).

Inches from muzzle.	Original diameter of bore.	Diameter after 24 rounds.	Enlargement.	Inches from muzzle.	Original diameter of bore.	Diameter after 24 rounds.	Enlargement.
	Inches.	*Inches.*	*Inch.*		*Inches.*	*Inches.*	*Inch.*
169	6.500	6.502	0.002	91	6.501	6.502	0.001
168	6.499	6.502	.003	90	6.501	6.502	.001
167	6.499	6.502	.003	89	6.501	6.502	.001
166	6.499	6.502	.003	88	6.501	6.502	.001
165	6.499	6.501	.002	87	6.501	6.502	.001
164	6.499	6.501	.002	86	6.501	6.502	.001
163	6.499	6.501	.002	85	6.501	6.502	.001
162	6.499	6.500	.001	84	6.501	6.502	.001
161	6.490	6.500	.001	83	6.501	6.502	.001
160	6.499	6.500	.001	82	6.501	6.502	.001
159	6.500	6.500	.000	81	6.501	6.502	.001
158	6.500	6.500	.000	80	6.501	6.502	.001
157	6.500	6.501	.001	79	6.501	6.502	.001
156	6.500	6.501	.001	78	6.501	6.502	.001
155	6.500	6.501	.001	77	6.501	6.502	.001
154	6.500	6.501	.001	76	6.501	6.502	.001
153	6.501	6.501	.000	75	6.501	6.501	.000
152	6.501	6.502	.001	74	6.501	6.501	.000
151	6.501	6.502	.001	73	6.501	6.501	.000
150	6.501	6.502	.001	72	6.501	6.501	.000
149	6.501	6.502	.001	71	6.501	6.501	.000
148	6.501	6.502	.001	70	6.501	6.501	.000
147	6.501	6.502	.001	69	6.501	6.501	.000
146	6.501	6.502	.001	68	6.501	6.501	.000
145	6.501	6.502	.001	67	6.501	6.501	.000
144	6.501	6.502	.001	66	6.501	6.501	.000
143	6.501	6.502	.001	65	6.501	6.501	.000
142	6.501	6.502	.001	64	6.500	6.501	.001
141	6.501	6.502	.001	63	6.500	6.501	.001
140	6.501	6.502	.001	62	6.500	6.501	.001
139	6.501	6.502	.001	61	6.500	6.501	.001
138	6.501	6.502	.001	60	6.500	6.501	.001
137	6.501	6.502	.001	59	6.500	6.501	.001
136	6.501	6.502	.001	58	6.500	6.501	.001
135	6.501	6.502	.001	57	6.500	6.501	.001
134	6.501	6.502	.001	56	6.500	6.501	.001
133	6.501	6.501	.000	55	6.500	6.501	.001
132	6.501	6.501	.000	54	6.500	6.501	.001
131	6.502	6.501	-.001	53	6.500	6.501	.001
130	6.502	6.501	-.001	52	6.500	6.501	.001
129	6.502	6.502	.000	51	6.500	6.501	.001
128	6.502	6.502	.000	50	6.500	6.501	.001
127	6.502	6.502	.000	49	6.501	6.501	.000
126	6.502	6.502	.000	48	6.501	6.501	.000
125	6.502	6.502	.000	47	6.501	6.501	.000
124	6.502	6.502	.000	46	6.501	6.502	.001
123	6.502	6.502	.000	45	6.501	6.502	.001
122	6.502	6.503	.001	44	6.501	6.502	.001
121	6.502	6.502	.000	43	6.501	6.502	.001
120	6.502	6.502	.000	42	6.502	6.502	.000
119	6.502	6.502	.000	41	6.502	6.502	.000
118	6.502	6.502	.000	40	6.502	6.502	.000
117	6.502	6.502	.000	39	6.501	6.502	.001
116	6.502	6.502	.000	38	6.501	6.501	.000
115	6.502	6.502	.000	37	6.501	6.501	.000
114	6.502	6.502	.000	36	6.501	6.501	.000
113	6.502	6.502	.000	35	6.501	6.501	.000
112	6.502	6.502	.000	34	6.501	6.501	.000
111	6.502	6.502	.000	33	6.501	6.501	.000
110	6.502	6.502	.000	32	6.501	6.501	.000
109	6.502	6.502	.000	31	6.501	6.501	.000
108	6.502	6.502	.000	30	6.501	6.501	.000
107	6.502	6.502	.000	29	6.501	6.501	.000
106	6.502	6.502	.000	28	6.501	6.501	.000
105	6.502	6.502	.000	27	6.501	6.501	.000
104	6.502	6.502	.000	26	6.501	6.501	.000
103	6.502	6.502	.000	25	6.501	6.501	.000
102	6.502	6.502	.000	24	6.501	6.501	.000
101	6.502	6.502	.000	23	6.501	6.501	.000
100	6.501	6.502	.001	22	6.501	6.501	.000
99	6.501	6.502	.001	21	6.501	6.501	.000
98	6.501	6.502	.001	20	6.501	6.501	.000
97	6.501	6.502	.001	19	6.501	6.501	.000
96	6.501	6.502	.001	18	6.501	6.501	.000
95	6.501	6.502	.001	17	6.501	6.501	.000
94	6.501	6.502	.001	16	6.501	6.501	.000
93	6.501	6.502	.001	15	6.501	6.501	.000
92	6.501	6.502	.001	14	6.501	6.501	.000

Table showing enlargement of bore and chamber of 6.5-inch breech-loading rifle (Mann)—Continued.

Inches from muzzle.	Original diameter of bore.	Diameter after 24 rounds.	Enlargement.	Inches from muzzle.	Original diameter of bore.	Diameter after 24 rounds.	Enlargement.
	Inches.	*Inches.*	*Inch.*		*Inches.*	*Inches.*	*Inch.*
13	6.501	6.501	0.000	6	6.501	6.502	0.001
12	6.501	6.501	.000	5	6.501	6.502	.001
11	6.501	6.502	.001	4	6.501	6.502	.001
10	6.501	6.502	.001	3	6.501	6.502	.001
9	6.501	6.502	.001	2	6.500	6.501	.001
8	6.501	6.502	.001	1	6.500	6.501	.001
7	6.501	6.502	.001				

CHAMBER.

Inches from breech.	Diameter after 8 rounds.	Diameter after 24 rounds.	Enlargement from 8th to 24th rounds.	Inches from breech.	Diameter after 8 rounds.	Diameter after 24 rounds.	Enlargement from 8th to 24th rounds.
	Inches.	*Inches.*	*Inch.*		*Inches.*	*Inches.*	*Inch.*
35	6.821	6.822	0.001	18	6.820	6.821	0.001
34	6.820	6.823	.002	17	6.821	6.821	.000
33	6.820	6.822	.002	16	6.821	6.824	.003
32	6.820	6.822	.002	15	6.822	6.824	.002
31	6.820	6.823	.003	14	6.823	6.825	.002
30	6.822	6.823	.001	13	6.825	6.826	.001
29	6.820	6.823	.003	12	6.826	6.826	.000
28	6.820	6.823	.003	11	6.826	6.826	.000
27	6.820	6.823	.003	10	6.826	6.827	.001
26	6.820	6.823	.003	9	6.826	6.827	.001
25	6.820	6.823	.003	8	6.826	6.827	.001
24	6.820	6.823	.003	7	6.825	6.827	.002
23	6.820	6.823	.003	6	6.824	6.827	.003
22	6.820	6.823	.003	5	6.823	6.828	.005
21	6.820	6.823	.008	4	6.823	6.829	.006
20	6.820	6.823	.003	3	6.823	6.830	.007
19	6.820	6.822	.002	2	6.823	6.831	.008

Record of firing with 6.5-inch breech-loading rifle (Mann),

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 108 feet 9 inches from muzzle.	Recoil.
			Kind.	Weight.	Kind.	Weight.				
				Lbs.		*Lbs.*	° ′	*Lbs.*	*Feet.*	*Feet.*
Barometer, 29.996; thermometer, 85.2; humidity, 67,	1	Sept. 9	Du Pont's sphero-hexagonal L. C. Density, 1.815; granulation, 123.	20	Mann solid (new).	109	0 15	7, 500	1, 106	1. 75
	2	Sebt. 9		20		109	0 10	8, 000	Lost.	1. 25
	3	Sept. 9		25		109	0 12	10, 500	1, 344	1. 92
	4	Sept. 9		25		109	0 12	12, 000	1, 351	1. 92
	5	Sept. 9		30		109	0 15	17, 750	1, 534	2. 92
	6	Sept. 9		30		109	0 15	15, 500	1, 498	2. 83
Barometer, 30.085; thermometer, 83.7; humidity, 65.	7	Sept. 10		35		109	0 15	24, 500	1, 676	3. 66
	8	Sept. 10		35		109	0 15	23, 000	1, 630	3. 52
	9	Sept. 10		35		109	0 15	26, 250	1, 639	3. 66
	10	Sept. 10		35		109	0 15	24, 000	1, 660	3. 66
	11	Sept. 10		35		109	0 15	23, 750	1, 630	3. 75
	12	Sept. 10		35		109	0 15	23, 500	1, 628	3. 66

at Sandy Hook, N. J., from September 9 to October 8, 1884.

Wind, strength and direction.	Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.			
From front and right 48°; 8 miles an hour.	Fired into sand butt No. 2.	Head of securing-bolt for elevating-screw broken; repaired.		The gas-check used throughout these rounds was made of Butler sabot metal, and, except in round six, when there was considerable escape of gas, closed the breech fairly well. After each round subsequent to number 6 a burr had to be filed off from the outer edge of the check. It was removed easily by hand after firing, excepting in the case of rounds 11 and 12, when the tongs had to be used. For the first eight rounds a 245-pound Gruson shot was suspended from the muzzle to counterbalance the breech preponderance when the gun was unlocked and facilitate opening the gun. From rounds 9–12 the Gruson shot was replaced by a heavier chain around neck of gun, and at all times the gun was opened easily by two men. Three projectiles were used, differing in the character of soft-metal band. Rounds 1 to 8, marked A1, band metal containing 65.4 parts lead, 33 parts tin, 1.6 parts copper. Rounds 9 and 10, marked A2, made of Babbitt metal. Rounds 11 and 12, marked A3, containing 2.5 parts copper, 15 parts tin, 75 parts lead, 7.5 parts antimony. At least one of each kind of these projectiles key-holed in the butt. Of eight recovered, one only, and that one fired with 20 or 25 pounds of powder, showed marks of the rifling; with the others the soft metal was sheared off and in some cases entirely removed from the shot.
From front and left 42°; 3 miles an hour.		Gun washed out, examined, and star-gauged.	Considerable amount of unburnt powder.	

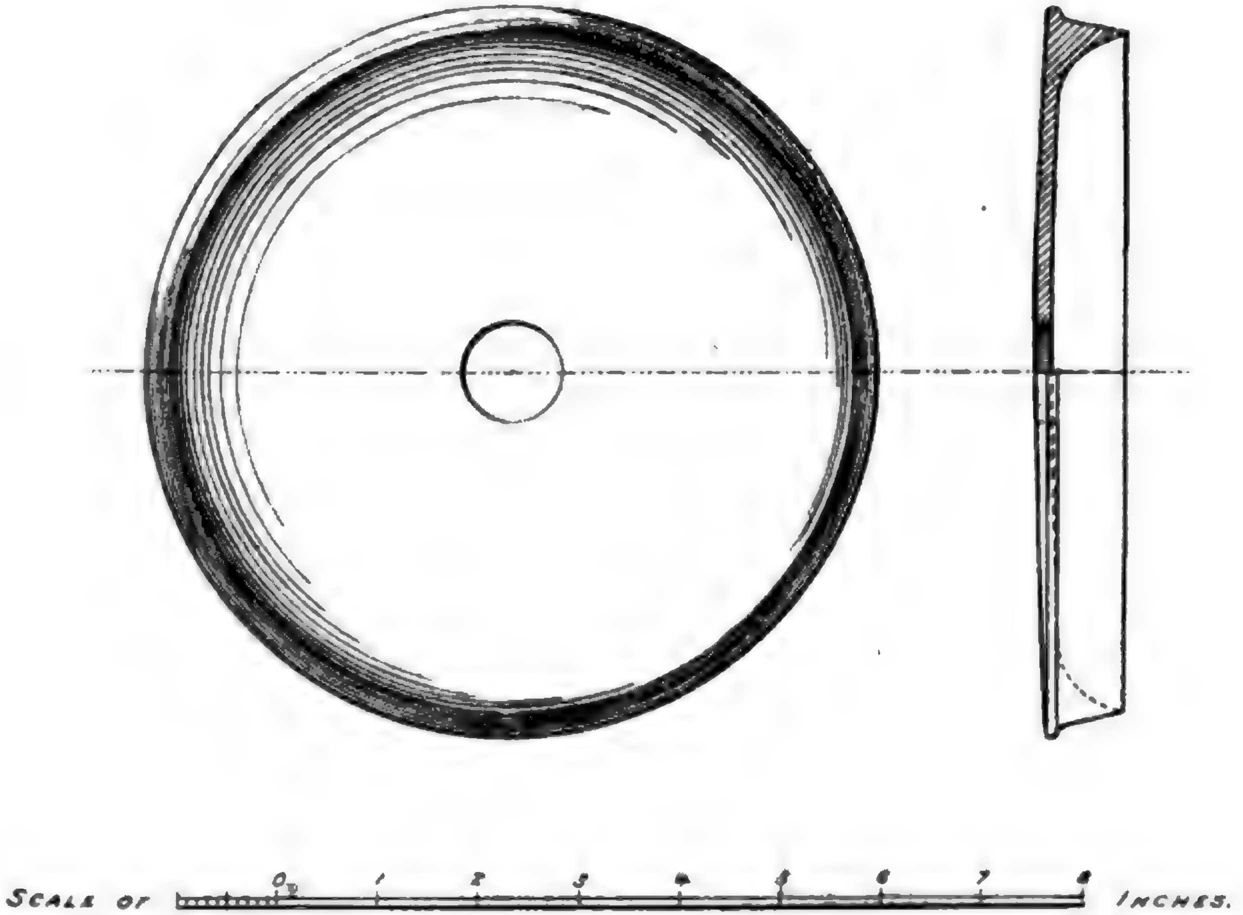
Record of firing with 6.5-inch breech-loading rifle (Mann),

	Number of fire.	Time.	Powder.		Projectile.		Elevation.	Pressure per square inch of bore (Rodman).	Instrumental velocity 104 feet 8 inches from muzzle.
			Kind.	Weight.	Kind.	Weight.			
		1884.		*Lbs.*		*Lbs.*	° ′	*Pounds.*	*Feet.*
P. M. Barometer, 30.196; thermometer, 71; humidity, 83.	13	Oct. 1	Du Pont's sphero-hexagonal L. C. Density, 1.815; granulation, 123.	37	Mann solid (new), 1 copper band.	109	0 25	26, 500	1, 747
	14	Oct. 1		37		109	0 25	27, 250	1, 716
									104′ 1″
P. M. Barometer, 29.895; thermometer, 72; humidity, 51.	15	Oct. 7		37	Mann solid (new). 1 solid copper band with single V-groove.	109	0 25	26, 250	1, 737
	16	Oct. 7		37		109	0 25	23, 250	1, 720
	17	Oct. 7		37		109	0 25	21, 500	1, 711
	18	Oct. 7		37		109	0 25	22, 500	1, 707
	19	Oct. 7		37		109	0 25	23, 000	1, 708
									104′ 4″
A. M. Barometer, 29.946; thermometer, 65; humidity, 72.	20	Oct. 8		37	Mann solid (new). With single trapezoidal groove.	109	0 25	25, 250	1, 729
	21	Oct. 8		37	1 solid copper band with single trapezoidal groove with longer bevel in rear.	109	0 25	24, 250	1, 715
P. M. Barometer, 29.782; thermometer, 69; humidity, 71.	22	Oct. 8		40		109	0 25	27, 500	1, 735
	23	Oct. 8		40	1 solid copper band with single trapezoidal groove.	109	0 25	25, 000	1, 726
	24	Oct. 8	Du Pont's sphero hexagonal K. H. C. Density, 1.775; granulation, 123.	37		109	0 25	....	1, 748

at Sandy Hook, N. J., from September 9 *to October* 8, 1884—Continued.

Recoil.	Wind, strength and direction.		Special remarks about each fire, such as effect on piece, sound of projectile in flight, scattering of fragments, etc., etc.
Feet. 3.75	From rear and right 87°; 6 miles an hour.	Fired into sand butt. Projectiles took grooves well. Gun closed and opened easily with very slight escape of gas.	Gas-check Butler sabot metal (same check both rounds). Projectiles recovered from sand butt. Bands showed full impression of rifling, with very little slip. Rounds 13 and 14 solid copper band substituted for soft-metal band in rear, and front band turned down flush with body of shot. Closed and opened easily; light escape of gas.
3.75			
3.92	From rear and right 43°; 13 miles an hour.		Butler sabot metal gas-check used in these rounds: 15, 16, 17, 18, and 19; having previously been used in rounds 13 and 14. Removed by hand except in round 17.
3.83			Gun closed and opened easily.
3.92			Very slight escape of gas.
3.76			After this round gas escaped from both vents, though the right vent had been drilled only as far as bushing. Projectiles recovered from butt showed full impression of rifling and no slip.
3.83			
3.67	From front and left, 87°; 11 miles an hour.		
3.67			
3.83	From front and right, 3°; 20 miles an hour.		
3.82			After round 23 gas escaped between breech-block and body of gun; an incident said to have occurred on two previous occasions when a new gas check was first used. After each round it was observed that the union of the gun and breech-block had changed about one-tenth of an inch.
......			Rounds 23 and 24, new gas-check (the third) of Butler sabot metal used in these rounds. At round 24 breech of gun blew off. The steel cross-head was fractured about 3 inches from its left tenon and the remainder, with the breech screw, was thrown as a single fragment 54 feet to the rear, passing directly through a heavy wooden screen. One large fragment of the cast-iron breech-block was found directly under the gun, and another of equal size on the beach over 200 yards to the left and rear. The breech straps were spread out, but otherwise uninjured, and the carriage but slightly. The elevating-screw was, of course, torn off, and the gearing for opening the gun, with bolts and nuts here and there strewn around in every direction as various sized fragments. Only a small piece of the housing of the pressure-plug was found. The body of the gun was entirely uninjured.

GAS CHECK FOR MANN'S 6½ INCH B.L.CONVERTED RIFLE.

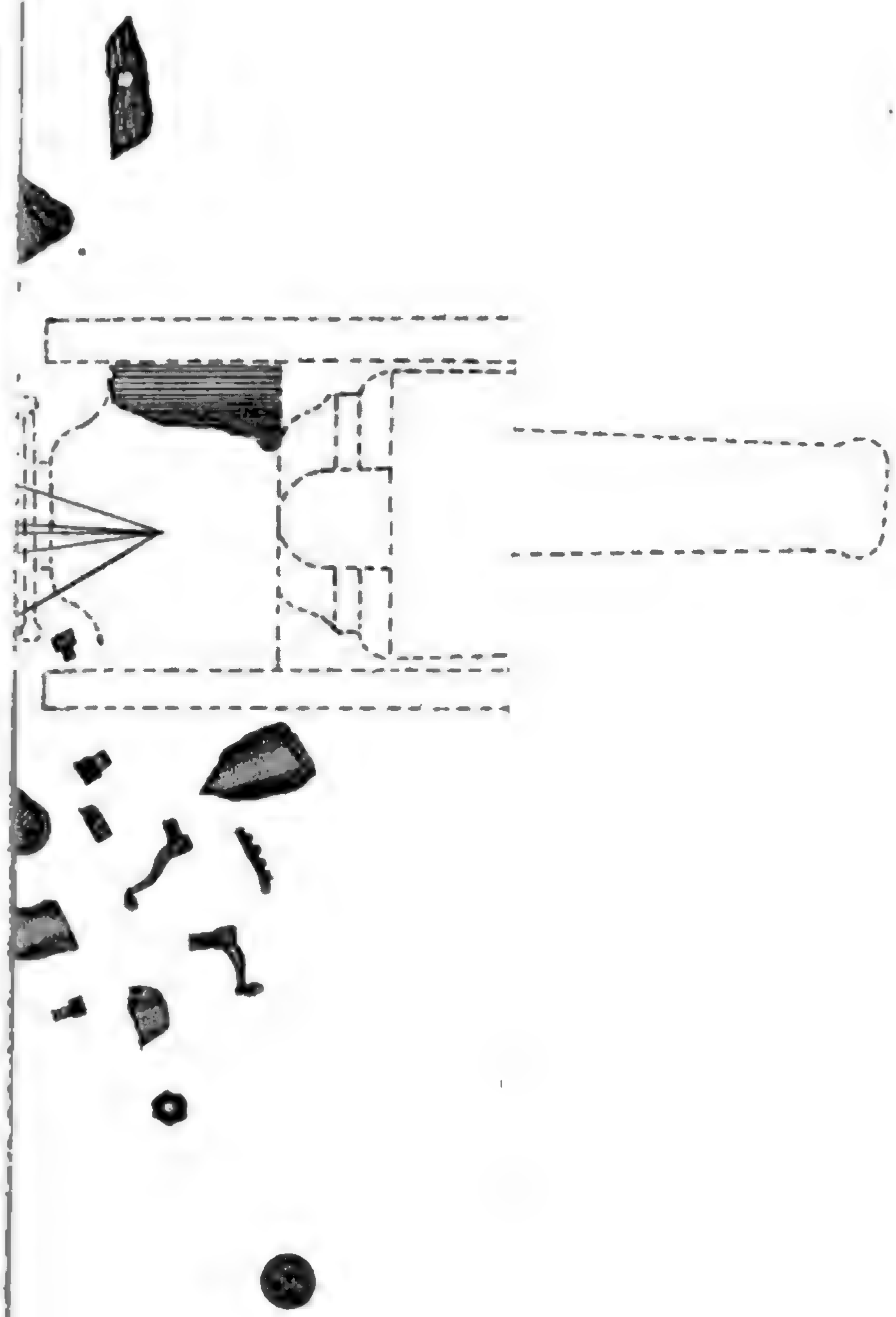


BOARD FOR TESTING RIFLED CANNON &C.
GOVERNORS ISLAND OCT. 15TH 1884.

PLATE III.

FRAGMENTS

RIFLE CONVERTED

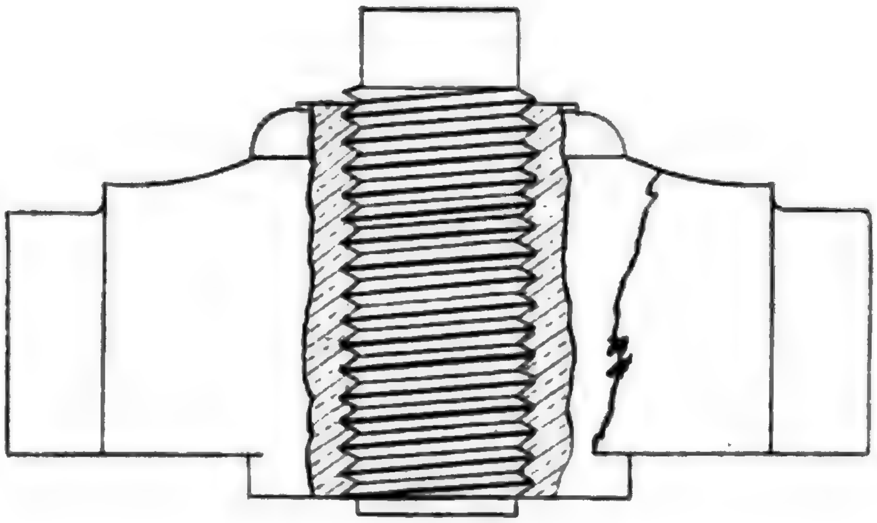


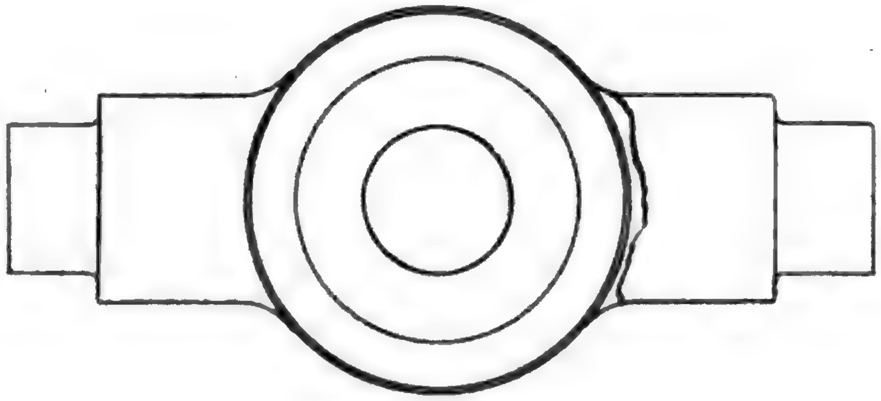
ING RIFLED CANNON &C.
OVERNORS ISLAND OCT 15th 1884

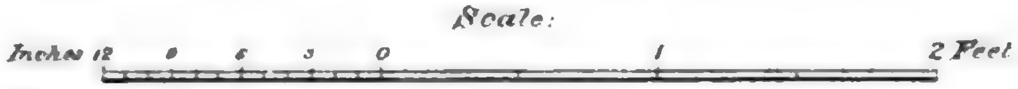
PLATE IV.

FRACTURED BREECH TRANSOM

MANN'S 6½ INCH B.L. RIFLE CONVERTED.







BOARD FOR TESTING RIFLED CANNON &C.
GOVERNORS ISLAND OCT. 15TH 1884.

Appendix 23—1884.

APPENDIX 24.

TABLE OF THE HOTCHKISS SINGLE-BARREL RAPID FIRING NON-RECOIL GUNS.

	These guns use the ammunition of the revolving cannon of same caliber.			High-power guns.			
Caliber ......millimeters..	37	47	53	37	a47	b47	57
Length of bore ......do......	740	1, 175	1, 272	1, 406	1, 786	1, 880	2, 280
Length of bore, in calibers......	20	25	24	38	38	40	40
Length of gun ......millimeters..	840	1, 325	1, 605	1, 506	1, 954	2, 048	2, 515
Length of gun, including stock or shoulder-piece ......millimeters..	1, 140	1, 825	2, 125	2, 020	2, 500	2, 600	3, 035
Weight of gun, including stock or shoulder-piece ......kilograms..	35	100	156	120	180	230	350
Weight of pivot... ......do......	17	35	56	50	56	60	80
Weight of socket, or of socket with stand,* kilograms	10	40	60	250	250	300	360
Weight of steel shell......grains..	512	1, 075	1, 700	800	1, 500	1, 500	2, 720
Bursting charge ......do ...	15	45	60	30	60	60	115
Length of steel shell, in calibers	2. 57	2. 5	3	4	3. 66	3. 66	3. 88
Charge of powder......grains..	80	220	410	320	500	750	850
Total length of cartridge with projectile, millimeters	167	234	319	370	395	515	477
Total weight of complete cartridge grains..	685	1, 535	2, 390	1, 420	2, 400	2, 780	4, 230
Initial velocity of projectile ......meters..	402	450	450	600	500	600	550
Pressure	....	....	....	....	....	2, 300	....
Total muzzle energy of projectile, in kilogram meters......	4, 217	11, 100	17, 548	18, 482	19, 116	27, 527	41, 944
Thickness of iron plate which the projectile will perforate .. ..millimeters..	30	50	65	....	80	120	....
Rapidity of fire, per minute, careful sighting not included......	20	20	20	20	20	18	18
Number of men required to work the gun..	1	2	2	2	2	2	2

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*The high-power guns are usually mounted on a stand, which is bolted down on the deck. The sockets for the other guns are bolted on the hand-rail or any other convenient part of the ship.

APPENDIX 25.

CONSTRUCTION REPORT OF THE 6½-INCH MANN BREECH-LOADING RIFLE.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT.

(1 plate.)

The body of this gun is converted from a 10-inch Rodman smooth-bore gun (No. 176, W. Pt. Fdy., No. 978) by inserting a steel tube, open at each end, shrinking on a steel jacket over the breech, and shrinking on a steel trunnion ring whose rear face is 6 inches in front of the forward end of the jacket.

The breech mechanism consists of a cast-iron breech-block recessed into a steel transom, which carries a steel breech-screw for bringing the breech-block in contact with the base of the breech. The transom is mortised into two steel side straps, which transmit the strain upon the breech to the trunnions upon the body of the gun. A second set of trunnions are placed on the exterior faces of these side straps to support the gun upon its carriage. The centers of the trunnions on the side straps are 23 inches in rear of the centers of those on the body.

The tube, jacket, trunnion-ring, side straps, transom, and breech-screw are all made of Whitworth fluid-compressed steel. The quality of the material and the finish of these parts testify to the excellence of the work done by that celebrated manufacturer. The tube was finish-turned, chambered, and rifled when received. The finish-turning of the exterior necessitated very delicate manipulation at this foundry in boring the casing in order to keep within the small limits required. It is preferable in manufacture to first bore out the casing and then turn the tube down to the limits prescribed. Hence tubes should not be finished on the exterior until they arrive at the place of assembly.

A retaining ring of steel is screwed on the rear end of the tube. The exterior of this ring fits mechanically into the corresponding counterbore of the cast-iron casing.

The breech-screw is set up and relieved by means of a tappet-lever attached to the rear.

The mechanism is opened and closed for loading by means of a crank shaft passing transversely through the side straps, carrying two brass pinion-wheels which engage two corresponding racks screwed to the sphero-segmental surface forming the face of the breech. These racks are placed one on each side of the bore and extend downwards from points on a line with the center of the bore.

PRINCIPAL DIMENSIONS OF BORE.

	Inches.
Total length (17 feet=31⅜ calibers)	204.
Diameter of rifled portion	6.5
Length of rifled portion	168.5
Diameter of chamber	6.82
Length of chamber (cylindrical part)	34.
Length of chamber (conical part)	0.75
Total length of chamber	34.75
Length of recess for gas-check	0.75
Thickness of walls of tube over chamber	2.215
Thickness of walls of tube under casing	2.375
Thickness of walls at front end of casing	4.1
Thickness of walls at neck	2.4375
Thickness of walls at swell of muzzle	3.75

RIFLING.

The rifling consists of thirteen lands and thirteen grooves of equal width, and terminates upon the bevel.

Width of lands and grooves	inches..	0.7854
Depth of grooves	do....	0.1
Radius of angles at bottom of grooves	do....	.05
Diameter of bore over lands	do....	6.5
Diameter of bore over grooves	do....	6.7
Twist, one turn in 60 calibers, or	feet..	32.5

WEIGHTS OF PRINCIPAL PARTS.

	Pounds
Body	17,275
Breech-block	485
Transom	1,367
Side straps (2)	3,285
Breech-screw	275
Total weight of gun	22,994

PREPONDERANCE.

	Pounds.
Of body, on loading trunnions (forward set), breech	293
Of whole gun, on carriage or firing trunnions (rear set), muzzle	2,213

For detailed description of gun and claims of inventor, see specifications forming part of Letters Patent No. 257,230, dated May 2, 1882, and specifications forming part of Letters Patent No. 257,823, dated May 9, 1882, transmitted herewith and forming part of this report. For details of weights and dimensions see inspection report inclosed.

VENTING.

The vent is for center fire. A copper vent piece or bushing is set in the cast-iron breech piece. The vent is bored axially on a line with the axis of the bore for a short distance, where it is intersected at an obtuse angle by a hole bored from the upper surface of the breech piece and lying in a plane passing through the axis of the bore (when breech is closed) and inclined to the vertical plane through the same axis. A second vent is placed symmetrically on the opposite side of the vertical plane, but is bored only to the outer surface of the copper bushing.

FABRICATION.

The work of conversion was performed by the South Boston Iron Works, at South Boston, Mass. The Rodman gun casing was turned and bored to the given dimensions, and the steel tube inserted with a play of .004 inch, though it was intended to have them the same size, and heat the casing for tube-insertion.

The steel jacket and trunnion band were then consecutively shrunk on.

ASSEMBLING.

Tube in casing.

First trial.—The first attempt to insert the tube resulted in failure from defects of method and appliances.

The operations were as follows:

Tube.—Both ends of this were closed by wooden plugs. A five-eighths inch gas pipe, extending nearly to the breech, was inserted through the center of the muzzle plug to admit water conducted from a hydrant through an attached hose. The water was to keep the tube cool. The waste water was carried off by a 1-inch iron pipe with hose attached. The pipes and hose proved too small for the purpose. The whole was arranged according to the Rodman plan. A clamp and chain fastened to the muzzle end of the tube was hooked to a derrick for hoisting and lowering.

Cast-iron casing.—This was placed breech down upon an iron ring about 2.5 inches thick, supported by bricks placed upon the surface of the ground. Five sections of an old boiler were placed end to end, vertically, so as to inclose the casing, which extended 12 inches beyond this shell. Numbering the sections from the bottom, Nos. 1 and 2 were riveted together, the 3d and 4th, similarly prepared, were placed loosely upon the first two, and the 5th loosely upon the top of the fourth section.

Firing.—Shavings were filled in around the cast-iron body and the fire lighted. The fuel used was strips of dry pine added from time to time.

Details.—7.45 a. m., fire lighted; 8.15 a. m., fuel added; 8.52 a. m., fuel added; 9.12 a. m., fuel added; 9.25 a. m., fuel added; 9.52 a. m., commenced to lower tube in casing; 9.55 a. m., tube stuck in casing 52 inches from required position; 10.00 a. m., fuel added to expand casing more, but without success; 10.37 a. m., water turned off and fire allowed to go down; 10.44 a. m., water hot, steam and hot water escaping at intervals; 10.49 a. m., cold water turned on, escape of steam and water ceased; 10.52 a. m., water began to flow again; 10.55 a. m., water turned off; 10.57 a. m., steam and water escaping; 11 a. m., steam escaping, and water, at intervals; 11.02 a. m., hot water escaping through efflux pipe; 11.09 a. m., plug came out of bottom of tube, letting out water and steam under considerable pressure, water turned off and fire extinguished.

During the trial the loose boiler sections were disarranged and tipped to one side. A brisk breeze blew the fire to one side, causing unequal heating; and the casing was so long that the blaze did not extend high enough to expand the upper part of the casing sufficiently to admit the tube. The arrangements were very crude and insufficient.

The tube was subsequently removed from the casing by means of a 95-ton hydraulic jack.

Second trial.—For this attempt the casing was placed in a casting pit in the gun-foundry, where suitable arrangements existed for heating properly. The mouth of the pit, which was level with the muzzle of the casing, was covered with plates of iron. The tube was closed at each end by plates of iron, under which were placed rubber gaskets, and all securely held in position by a ¾-inch iron rod extending the whole length of the tube. The inlet pipe extending to bottom of tube was 1 inch in diameter, to which was fitted a 1¾-inch hose. The outlet or waste-water pipe was 1½ inches in diameter. The hoisting and lowering was done by a crane.

The upper end of the casing was closed by a sheet-iron plate having a hole in the center to admit the metallic stem of a Bulkley pyrometer, for determining the temperature.

The grate was filled with a layer of shavings and charcoal, on which some coal was placed. The fire was lighted at 5.40 p. m., and tended by a watchman during the night, who allowed the fire to go down slightly about 4.30 a. m. the following morning.

Details.—June 17, 5.40 p. m., fire lighted in pit. June 18, 4.30 a. m., fire getting low; 7.25 a. m., pyrometer inserted; 7.45 a. m., indicated temperature 260°; 7.52 a. m., fuel added—old pine patterns and little charcoal; 7.57 a. m., fuel added (wood and charcoal); 8.10 a. m., fuel added (wood); 8.10 a. m., pyrometer reading 350°; 8.30 a. m., pyrometer reading 310°; 8.40 a. m., pyrometer reading 350°; 9.00 a. m., pyrometer reading 370°; 9.20 a. m., pyrometer reading 390°; 9.37 a. m., pyrometer reading 400°; 9.50 a. m., pyrometer reading 420°; 10.00 a. m., pyrometer reading 425°; 10.15 a. m., pyrometer reading 440°; 10.38 a. m., pyrometer reading 475°; 10.51 a. m., pyrometer reading 460°; 11.04 a. m., pyrometer reading 470°; 11.25 a. m., pyrometer reading 475°; 11.35 a. m., water turned on in tube, and bad packing allowed leakage at upper end—35 minutes lost in repacking; 12.00 m., pyrometer reading 500°; 12.35 p. m., pyrometer reading 510°; 12.45 p. m., pyrometer reading 510°; 1.25 p. m., pyrometer reading 490°: 1.50 p. m., pyrometer reading 500°; 2.10 p. m., pyrometer reading 500°.

Removed pyrometer and covering from end of casing. Latter measured as well as heat would admit, and found to be expanded about .04 inch.

The crane with tube was then placed in position, the water turned on in tube until it overflowed, and the tube inserted as rapidly as possible, the downward movement being controlled by the brake.

The tube was lowered into the casing in 27 seconds. In 10 minutes waste water slightly warm. A full head of water was turned on, the overflow was then cold and so kept to the end. A three-fourths inch radially perforated iron pipe was bent so as to encircle the casing near the top and water admitted.

The radial jets cooled the upper end more rapidly than the rest of the mass and caused it to bind there first. The fire was allowed to burn down and water applied to extinquish it.

The muzzle end of the tube was found to be quite warm on the outside soon after the casing was set.

At 3 p. m. pit uncovered, fire completely extinguished, casing and upper end of tube allowed to cool gradually.

At 3.55 p. m., water turned off perforated outside pipe and partially turned off in tube, until it was found that the water was getting warm, when full pressure was let on and maintained until tube and casing cooled down.

At 4.55 p. m., casing but slightly warm, upper part of tube cold, waste water cold.

The gun was hoisted from pit, laid on floor, water emptied from tube, bore wiped and oiled.

SHRINKING ON STEEL JACKET.

The jacket was placed breech end down on an iron ring supported by brick laid upon the foundry floor, surrounded by a boiler-iron casing, and the space between filled half way to the top with shavings and wood. Top of jacket closed to keep out dust, and pyrometer inserted axially. The gun was fitted with cooling arrangement same as in second trial for insertion of tube, and suspended from a crane.

Details.—July 1, 8.30 a. m., fire lighted, and wood added from time to time; 10.07 a. m., pyrometer indicated 550°; 10.08 a. m., gun ready for lowering; $10^h 9^m 25^s$ a. m., gun lowered into jacket; $10^h 9^m 52^s$ a. m., gun in jacket (lowered in 27 seconds); water applied to exterior near top of jacket at once through perforated pipe for one minute; water off, three minutes; water on, three minutes; water off, ten minutes, then applied continually till 10.48 a. m.; 10.57 a. m., gun lifted from flask; 11.20 a. m., gun laid on floor, breech still quite hot; oil with which casing was covered oozing out, due to shrinkage. Cold water kept running through tube till gun cooled.

SHRINKING ON TRUNNION BAND.

This was done similarly to the jacket except it was in the open air. July 23, 1884, 1 p. m., fire lighted; 1.40 p. m., expanded sufficient to admit gauge; 1.45 p. m., band removed from flask; 1.47 p. m., band on gun-lathe horizontal; 1.50 p. m., clamps applied to draw band up to shoulder. Band expanded 0.″25 diametrally more than necessary; 1.53 p. m., water turned on exterior of band sprinkler did not operate well, and watering pot substituted; 1.58 p. m., hose used to pour water over exterior on one minute; 2.10–2.14 p. m., water on rear end of band; 2.14 p. m., water off; 2.15 p. m., water on front end of band; 2.25–2.27 p. m., water on casing in rear of band; 2.30 p. m., water off; 2.31 p. m., band cool except trunnions; water turned on over whole surface of ring; steel jacket in rear of ring too hot to bear hand any length of time; 2.34 p. m., could bear hand on band; 3.00 p. m., still very warm, left to cool.

The gun was finished, assembled, and turned over to the Ordnance Department for inspection.

For detailed dimensions I would respectfully refer to the inspection report forwarded herewith, and forming part of this report.

The whole superintendence of this conversion, according to the terms of the contract, devolved upon the inventor, Mr. Mann, who was present almost constantly, and arranged every detail.

Report of inspection and proof of 6.5-inch Mann breech-loading rifle No. 1, fabricated, at the South Boston foundry, under contract of Chief of Ordnance, U. S. A., dated July 14, 1883.

Subject of measurement.	Dimensions.		Variations—actual.
	Prescribed.	Actual.	
	Inches.	*Inches.*	
Total length of gun	236.75	236.75	0
Total length of tube	204.	204.	0
Length of rifled part	168.5	168.5	0
Length of chamber	34.	34.	0
Length of frustum in front of chamber	0.75	0.75	0
Length of frustum in rear of chamber	0.75	0.75	0
Diameter of bore across lands	6.5	6.5	0
Diameter of bore across grooves	6.7	6.691	—.009
Width of grooves and lands	.7854	.7854	0

Report of inspection and proof of 6.5-*inch Mann breech-loading rifle No.* 1, *&c.*—Cont'd.

Subject of measurement.	Dimensions.		Variations—actual.
	Prescribed.	Actual.	
	Inches.	*Inches.*	
Depth of grooves	.1	.955	—.045
Number of grooves and lands	26.	26.	0
Grooves filleted with radius of	.05	.05	0
Pitch of rifling	1 in 60 cal.	1 in 60 cal.	0
Diameter of chamber	6.82	6.815	—.005
Length of screw-head	9.	9.	0
Length of cylinder from screw-head to bell-mouth	115.75	115.75	0
Length of bell-mouth	6.5	6.5	0
Radius of bell-mouth	18.	18.	0
Length of cylinder in front of mouth	.75	.75	0
Length of tube from end of casing to muzzle	69.	69.	0
Exterior diameter of tube from end of screw-head to bell-mouth	11.25	11.242	—.008
Corresponding diameter of bore of casing	11.25	11.246	—.004
Corresponding shrinkage	0	0	0
Exterior diameter of tube at cylinder in front of bell-mouth	14.7	14.7	0
Diameter at neck of muzzle	11.375	11.375	0
Diameter at swell of muzzle	14.	13.954	—.046
Diameter of fillet	11.	10.993	—.007
Length of casing	135.	135.	0
Length of recess for retaining ring	9.	9.	0
Length of bell-mouth from casing	6.5	6.5	0
Play between tube and casing at bell-mouth	0	0	0
Rear diameter of recess for retaining ring*	15.25	15.25	0
Rear diameter of retaining ring*	15.25	15.25	0
Corresponding play*	0	0	0
Front diameter of recess for retaining ring*	14.25	14.25	0
Front diameter of retaining ring*	14.25	14.25	0
Corresponding play	0	0	0
Length of retaining ring	9.	9.	0
Play between end of ring and shoulder of casing	0	0	0
Pitch of screw on retaining ring (threads per inch)	1.	1.	0
Length of jacket	55.5	55.47	—.03
Length of bearing surface for jacket on exterior of casing	55.5	55.5	0
Corresponding play	0	.03	†+.03
Interior diameter of jacket	21.	21.	0
Corresponding diameter of casing	21.021	21.018	—.003
Corresponding shrinkage	.021	.018	—.003
Exterior diameter of jacket at rear	28.5	28.494	—.006
Interior diameter of first shoulder of trunnion ring	23.875	23.873	—.002
Corresponding diameter of casing	23.898	23.892	—.006
Corresponding shrinkage	.023	.019	—.004
Interior diameter of second shoulder of trunnion ring	23.25	23.25	0
Corresponding diameter of casing	23.273	23.276	+.003
Corresponding shrinkage	.023	.026	+.003
Interior diameter of third shoulder of trunnion ring	22.625	22.626	+.001
Corresponding diameter of casing	22.647	22.647	0
Corresponding shrinkage	.022	.021	—.001
Interior diameter of fourth shoulder of trunnion ring	22.	21.998	—.002
Corresponding diameter of casing	22.022	22.023	+.001
Corresponding shrinkage	.022	.025	+.003
Length of each of four shoulders	3.25	3.25	0
Length of trunnion band	13.	13.	0
Diameter of trunnions	6.5	6.5	0
Length of trunnion	4.25	4.25	0
Distances between rim bases	29.	29.	0
Distances between faces of trunnions	37.5	37.52	+.02
Distance from muzzle to trunnions	136.	136.	0
Diameter of gun in rear of trunnions	25.25	24.959	—.291
Length of side straps	107.25	107.1875	—.0625
Thickness of side straps	4.25	4.25	0
Diameter of bearing for loading-trunnion	6.5	6.51	+.01
Distance of same from front end of strap	11.25	11.25	0
Distance of firing trunnion from end of strap	34.25	34.1225	—.1275
Diameter of firing trunnion	7.	6.995	—.005
Length of firing trunnion	3.5	3.5	0
Length of saddle bearing	5.	5.	0
Depth of saddle bearing	1.25	1.25	0
Distance of same from end of strap	68.	68.	0
Diameter of pinion-shaft bearing	1.75	1.75	0
Distance of same below longitudinal axis of strap	1.5	1.5	0
Distance of same from front end of strap	82.625	82.625	0
Length of mortise	10.25	10.21875	—.03125
Width of same	6.5	6.5	0
Distance of same from rear end of strap	13.875	13.875	0
Width of strap over bearing for loading trunnions	18.	18.125	+.125

* Mechanical fit, surface-ground.

† The jacket, in cooling, contracted about this amount. The interval was filled in by crowding.

Report of inspection and proof of 6.5-inch Mann breech-loading rifle No. 1, &c.—Cont'd.

Subject of measurement.	Dimensions.		Variations—actual.
	Prescribed.	Actual.	
	Inches.	*Inches.*	
Same between firing and loading trunnions	11. 25	11. 2	—. 05
Same over firing trunnions	15. 5	15. 5	0
Same between firing trunnions and mortise	11. 25	11. 25	0
Same over mortise	18. 5	18. 5	0
Length of cylindrical part of transom	17.	17. 1	+. 1
Diameter of same	16. 5	16. 5	0
Length of body of transom	11. 5	11. 5	0
Thickness of same	9.	9.	0
Length of tenon of transom	4. 25	4. 25	0
Thickness of same	6. 5	6. 5	0
Width of same	10. 25	10. 21875	—. 03125
Distance between shoulders of transom	29.	29. 03	+. 03
Length over all	37. 5	37. 5	0
Diameter of breech-screw over top of threads	8. 25	8. 25	0
Same over bottom of threads	7.	....	....
Pitch of screw (threads per inch)	. 8	. 8	0
Length of thread	18.	18.	0
Length of bearing for tappet-lever	2. 75	2. 75	0
Diameter of same	7.	7	0
Diameter of breech-block in front	28. 5	28. 5	0
Diameter of same in rear	16. 5	16. 45	—. 05
Length of breech-block	10.	10. 08	+. 08
Depth of loading slot in front	6. 75	6. 8	+. 05
Same in rear	5. 50	5. 437	—. 013
Width across top of slot	7. 4	7. 38	—. 02
Width of block between pinions	8. 75	8. 75	0
Distance between pinions	9.	9.	0
Clearance	. 125	. 125	0
Diameter of pinion shaft	2.	1. 99	—. 01
Diameter of same in side straps	1. 75	1. 72	—. 03
Side of square for crank	1. 375	1. 41	+. 035
Total length	47.	46. 75	—. 25
Length between shoulders	29.	29.	0
Length of part in side straps	6. 75	6. 5	—. 25
Length of crank bearing	2. 75	2. 75	0
Length of crank between centers	15. 5	14. 5	—1.
Length of handle	6.	6.	0
Diameter of pinions	4. 815	4. 815	0
Length of hub	2. 82	2. 82	0
Length of teeth	2.	2.	0
Number of teeth	13.	13.	0
Width of rack	2.	2.	0
Length of rack	13. 25	13. 25	0
Number of teeth in rack	13.	13.	0
Width of saddle	3. 5	3. 375	—. 125
Width of same in side straps	5.	5.	0
Distance between lugs	1. 25	1. 27	+. 02
Thickness of lugs	. 75	. 77	+. 02
Depth of same	4. 25	4. 30	+. 05
Width of same	3.	3.	0
Diameter of pin-holes	1. 25	1. 25	0
Length of link	18. 625	18. 625	0
Thickness of same	1. 25	1. 25	0
Width of same	3.	3.	0
Length of slot	11. 25	11. 25	0
Length of bracket	5.	5.	0
Width of same	6. 25	6. 25	0
Length of tappet-lever	20. 5	20. 9	+. 4
Length of handle of same	4. 875	5.	+. 12
Diameter of vent	. 2	. 2	0
Distance of exterior opening to left of axis of gun	4. 45	4. 45	0
Distance of same from breech of casing	3. 5	3. 5	0

WEIGHTS—COMPONENT PARTS.

	Pounds.
Tube and casing complete	17, 275
Two side straps	3, 285
Transom	1, 367
Breech-block	485
Breech-screw	275
Tappet lever	47
Brass washer and breech-screw	9
Bolt for breech-screw	2. 5

	Pounds.
Saddle with lugs	68
Four bolts for saddle	6
Pin in lugs of saddle	1.5
Bracket	13
Pin in bracket	1.5
Link	14
Pinion shaft	36
Two cranks for same	17
Two pinions	13
Two segmental gears	18
Two brass washers on trunnions of tube	16
Eight bolts for same	8
Two brass plates on tennons of transom	29
Eight bolts for same	8
Total weight of gun	22,994.5
Preponderance:	
Breech preponderance on loading trunnions	293
Muzzle preponderance on firing trunnions	2,213

I certify that the foregoing report is correct.

D. A. LYLE,
Captain of Ordnance, Inspector.

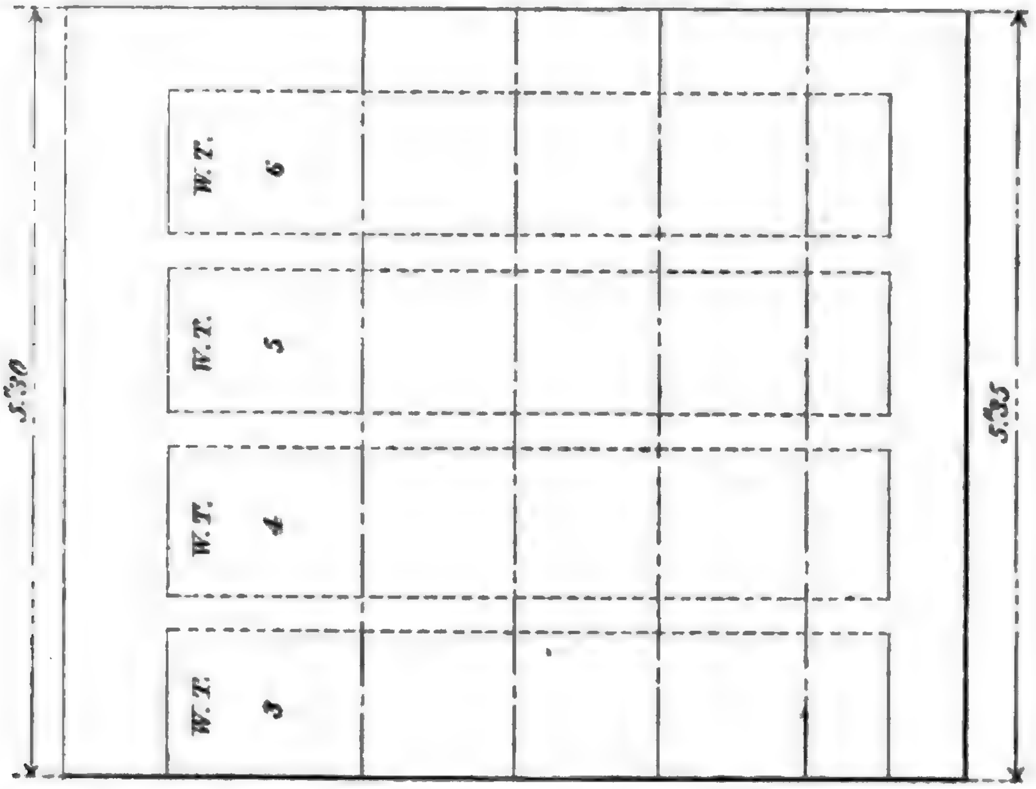
AUGUST 7, 1884.

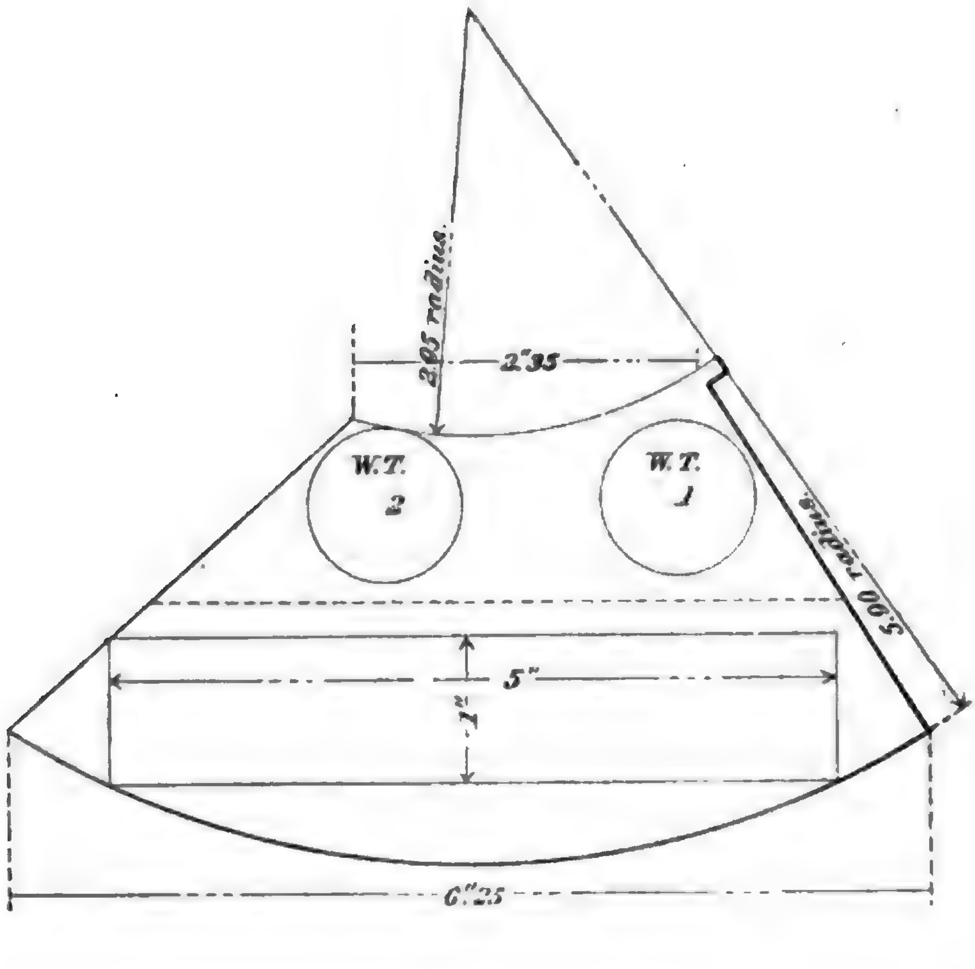
REPORT OF MECHANICAL TESTS, MADE WITH THE UNITED STATES TESTING MACHINE, CAPACITY 800,000 POUNDS, AT WATERTOWN ARSENAL, MASS., FOR THE ORDNANCE DEPARTMENT, U. S. ARMY, WASHINGTON, D. C.

TESTS BY TENSION: SIX SPECIMENS OF WHITWORTH STEEL FROM TUBE OF MANN GUN.

June 4, 1884.

Sketch showing position of samples taken from sector of tube of Mann gun.





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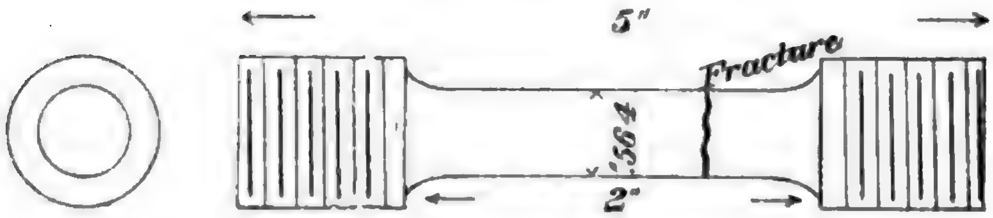

[Mark on bar, $\overset{\text{W. T.}}{1}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000200	.000200	0.	0.	
2,500	10,000	.000400	.000200	.000050	.000050	
3,750	15,000	.000700	.000300	.000100	.000050	
5,000	20,000	.000750	.000050	.000150	.000050	
6,250	25,000	.001000	.000250	.000150	0.	
7,500	30,000	.001150	.000150	.000150	0.	
8,750	35,000	.001200	.000050	.000150	0.	
10,000	40,000	.001400	.000200	.000150	0.	
10,250	41,000	.001500	.000100	....	....	
10,500	42,000	.001500	0.	....	....	
10,750	43,000	.001550	.000050	....	....	
11,000	44,000	.001550	0.	....	....	
11,250	45,000	.001600	.000050	.000150	0.	
11,500	46,000	.001600	0.	....	....	
11,750	47,000	.001650	.000050	....	....	
12,000	48,000	.001700	.000050	....	....	
12,250	49,000	.001750	.000050	....	....	
12,500	50,000	.001800	.000050	.000250	.000100	
12,750	51,000	.001900	.000100	....	....	
13,000	52,000	.001950	.000050	....	....	
13,250	53,000	.002000	.000050	....	....	
13,500	54,000	.002100	.000100	....	....	Elastic limit.
13,750	55,000	.002200	.000100	.000450	.000200	
14,000	56,000	.002350	.000150	....	....	
14,250	57,000	.002400	.000050	....	....	
14,500	58,000	.002550	.000150	....	....	
14,750	59,000	.002700	.000150	....	....	
15,000	60,000	.002950	.000250	.001100	.000650	
15,250	61,000	.003200	.000250	....	....	
15,500	62,000	.003600	.000400	....	....	
15,750	63,000	.004000	.000400	....	....	
16,000	64,000	.004750	.000750	....	....	
16,250	65,000	.005200	.000450	.002950	.001850	
16,500	66,000	.006000	.000800	....	....	
16,750	67,000	.006600	.000600	....	....	
17,000	68,000	.007500	.000900	....	....	
17,250	69,000	.008350	.000850	....	....	
17,500	70,000	.009500	.001150	.006850	.003900	
18,000	72,000	.010950	.001450	....	....	
18,500	74,000	.013500	.002550	....	....	
19,000	76,000	.015250	.001750	....	....	
19,500	78,000	.017150	.001900	....	....	
20,000	80,000	.019400	.002250	....	....	
20,500	82,000	.021850	.002450	....	....	
21,000	84,000	.024400	.002550	....	....	
21,500	86,000	.027150	.002750	....	....	
22,000	88,000	.030000	.002850	....	....	
22,500	90,000	.033550	.003550	....	....	Micrometer removed.
23,000	92,000	.0350	.001450	....	....	
23,500	94,000	.0375	.0025	....	....	
24,000	96,000	.0450	.0075	....	....	
24,500	98,000	.0550	.0100	....	....	
25,000	100,000	.0650	.0100	....	....	
25,500	102,000	.0775	.0125	....	....	
25,980	103,920	.1200	.0425	....	....	Ultimate strength.
23,900	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	103, 920
Elastic limit per square inch of original section	do	53, 000
Elongation per inch after rupture	inch	0. 1525
Elongation per inch under strain at elastic limit	do	. 0020
Reduction in diameter at point of rupture	do	. 094
Reduction in area after rupture, per centum of original section		30. 8
Position of rupture		one-half inch from neck.
Character of broken surface		fine granular with silvery luster; small dull spot at center.

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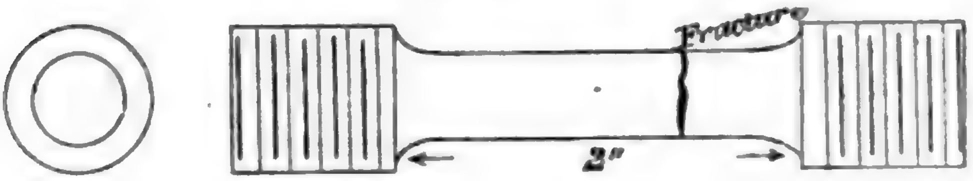


[Mark on bar, $\underset{2}{\text{W. T.}}$; diameter, .564 inch; sectional area, .25 square inch.]

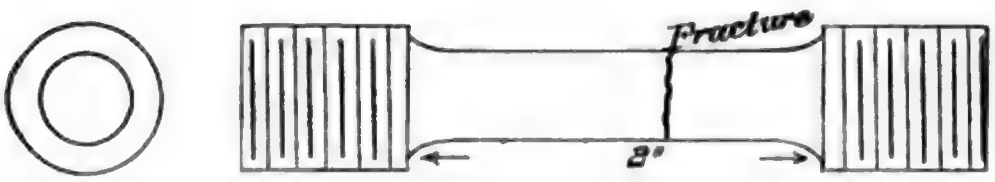
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	. 000100	. 000100	0.	....	
2, 500	10, 000	. 000350	. 000250	0.	....	
3, 750	15, 000	. 000600	. 000250	0.	....	
5, 000	20, 000	. 000700	. 000100	0.	....	
6, 250	25, 000	. 000900	. 000200	0.	....	
7, 500	30, 000	. 001050	. 000150	. 000050	. 000050	
8, 750	35, 000	. 001250	. 000200	. 000050	0.	
10, 000	40, 000	. 001500	. 000250	. 000150	. 000100	
10, 250	41, 000	. 001550	. 000050	....	....	
10, 500	42, 000	. 001600	. 000050	....	....	
10, 750	43, 000	. 001650	. 000050	....	....	
11, 000	44, 000	. 001700	. 000050	.....	....	
11, 250	45, 000	. 001750	. 000050	. 000300	. 000150	
11, 500	46, 000	. 001800	. 000050	....	....	
11, 750	47, 000	. 001850	. 000050	....	....	
12, 000	48, 000	. 001900	. 000050	....	....	
12, 250	49, 000	. 001950	. 000050	....	....	
12, 500	50, 000	. 002000	. 000050	. 000350	. 000050	
12, 750	51 000	. 002150	. 000150	....	....	
13, 000	52, 000	. 002250	. 000100	....	....	
13, 250	53, 000	. 002300	. 000050	....	....	
13, 500	54, 000	. 002400	. 000100	....	....	Elastic limit.
13, 750	55, 000	. 002500	. 000100	. 000750	. 000400	
14, 000	56, 000	. 002700	. 000200	....	....	
14, 250	57, 000	. 002800	. 000100	....	....	
14, 500	58, 000	. 002900	. 000100	....	....	
14, 750	59, 000	. 003050	. 000150	....	....	
15, 000	60, 000	. 003200	. 000150	. 001300	. 000550	
15, 250	61, 000	. 003550	. 000350	....	....	
15, 500	62, 000	. 004050	. 000500	....	....	
15, 750	63, 000	. 004250	. 000200	....	....	
16, 000	64, 000	. 005050	. 000800	....	....	
16, 250	65, 000	. 005700	. 000650	. 003350	. 002050	
16, 500	66, 000	. 006250	. 000550	....	....	
16, 750	67, 000	. 006900	. 000650	....	....	
17, 000	68, 000	. 007950	. 001050	....	....	
17, 250	69, 000	. 008600	. 000650	....	....	
17, 500	70, 000	. 009800	. 001200	. 007250	. 003900	
18, 000	72, 000	. 011300	. 001500	....	....	
18, 500	74, 000	. 013400	. 002100	....	....	
19, 000	76, 000	. 015500	. 002100	....	....	
19, 500	78, 000	. 017650	. 002150	....	....	
20, 000	80, 000	. 020050	. 002400	....	....	Rested under initial load one hour.
20, 500	82, 000	. 022050	. 002000	....	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
21, 000	84, 000	.024800	.002750	....	....	
21, 500	86, 000	.028000	.003200	....	....	
22, 000	88, 000	.031000	.003000	....	....	
22, 500	90, 000	.034800	.003800	....	....	
23, 000	92, 000	.0400	.0052	....	....	Micrometer removed.
23, 500	94, 000	.0450	.0050	....	....	
24, 000	96, 000	.0500	.0050	....	....	
24, 500	98, 000	.0575	.0075	....	....	
25, 000	100, 000	.0700	.0125	....	....	
25, 500	102, 000	.0650	.0150	....	....	
25, 690	102, 760	.1200	.0350	....	....	Ultimate strength.
23, 800	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity	7.8687
Hardness	24.12
Tensile strength per square inch of original section .... pounds	102, 760
Elastic limit per square inch of original section .... do	54, 000
Elongation per inch after rupture .... inch	0.1675
Elongation per inch under strain at elastic limit .... do	.0024
Reduction in diameter at point of rupture .... do	.104
Reduction in area after rupture, per centum of original section	33.6
Position of rupture	one-half inch from neck.
Character of broken surface	fine granular, silvery luster; dull spot at circumference of broken surface.

No. 300.



[Mark on bar, $\frac{\text{W. T.}}{3}$; diameter, .564 inch; sectional area, .25 square inch.]

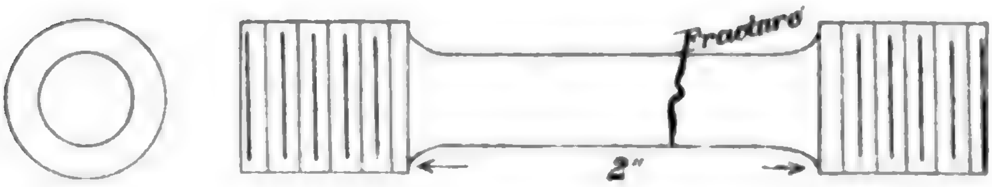
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000200	.000100	0.	....	
3, 750	15, 000	.000450	.000250	0.	....	
5, 000	20, 000	.000550	.000100	0.	....	
6, 250	25, 000	.000600	.000050	0.	....	
7, 500	30, 000	.000800	.000200	0.	....	
8, 750	35, 000	.001000	.000200	0.	....	
10, 000	40, 000	.001200	.000200	0.	....	
10, 250	41, 000	.001250	.000050	....	....	
10, 500	42, 000	.001300	.000050	....	....	
10, 750	43, 000	.001300	0.	....	....	
11, 000	44, 000	.001350	.000050	....	....	
11, 250	45, 000	.001350	0.	0.	....	
11, 500	46, 000	.001400	.000050	....	....	
11, 750	47, 000	.001400	0.	....	....	
12, 000	48, 000	.001450	.000050	....	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
12, 250	49, 000	.001450	0.	....	....	
12, 500	50, 000	.001500	.000050	.000050	.000050	
12, 750	51, 000	.001600	.000100	....	....	
13, 000	52, 000	.001650	.000050	....	....	
13, 250	53, 000	.001700	.000050	....	....	
13, 500	54, 000	.001750	.000050	....	....	
13, 750	55, 000	.001800	.000050	.000300	.000250	Elastic limit.
14, 000	56, 000	.002000	.000200	....	....	
14, 250	57, 000	.002200	.000200	....	....	
14, 500	58, 000	.002250	.000050	....	....	
14, 750	59, 000	.002350	.000100	....	....	
15, 000	60, 000	.002500	.000150	.000700	.000400	
15, 250	61, 000	.002550	.000050	....	....	
15, 500	62, 000	.002750	.000200	....	....	
15, 750	63, 000	.003100	.000350	....	....	
16, 000	64, 000	.003450	.000350	....	....	
16, 250	65, 000	.003900	.000450	.001800	.001100	
16, 500	66, 000	.004400	.000500	....	....	
16, 750	67, 000	.005050	.000650	....	....	
17, 000	68, 000	.005900	.000850	....	....	
17, 250	69, 000	.006350	.000450	....	....	
17, 500	70, 000	.006950	.000600	.005100	.003300	
18, 000	72, 000	.008550	.001600	....	....	
18, 500	74, 000	.010850	.002300	....	....	
19, 000	76, 000	.013000	.002150	....	....	
19, 500	78, 000	.014350	.001350	....	....	
20, 000	80, 000	.016500	.002150	....	....	
20, 500	82, 000	.018500	.002000	....	....	
21, 000	84, 000	.020850	.002350	....	....	
21, 500	86, 000	.023200	.002350	....	....	
22, 000	88, 000	.025800	.002600	....	....	
22, 500	90, 000	.028750	.002950	....	....	
23, 000	92, 000	.030950	.002200	....	....	
23, 500	94, 000	.034900	.003950	....	....	
24, 000	96, 000	.038250	.003350	....	....	Micrometer removed.
24, 500	98, 000	.0425	.004250	....	....	
25, 000	100, 000	.0500	.0075	....	....	
25, 500	102, 000	.0600	.0100	....	....	
26, 000	104, 000	.0650	.0050	....	....	
26, 500	106, 000	.0875	.0225	....	....	
26, 640	106, 560	.1225	.0350	....	....	Ultimate strength.
24, 900	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	106, 560
Elastic limit per square inch of original section	do....	55, 000
Elongation per inch after rupture	inch..	0. 1550
Elongation per inch under strain of elastic limit	do....	.0018
Reduction in diameter at point of rupture	do....	.084
Reduction in area after rupture, per centum of original section		27. 6
Position of rupture		three-fourths inch from neck.
Character of broken surface		granular, silvery luster, with dull spots near the center.

No. 301.



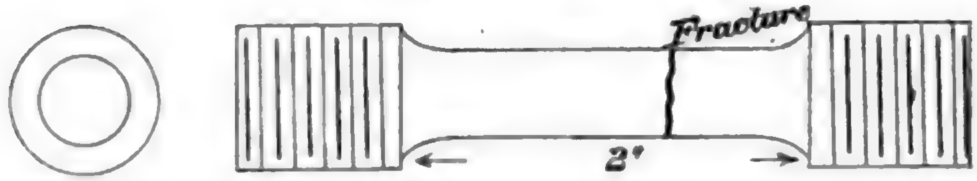
[Mark on bar $\overset{W.\ T.}{4}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000050	.000050	0.		
2, 500	10, 000	.000200	.000150	0.		
3, 750	15, 000	.000300	.000100	0.		
5, 000	20, 000	.000500	.000200	0.		
6, 250	25, 000	.000600	.000100	0.		
7, 500	30, 000	.000800	.000200	0.		
8, 750	35, 000	.001000	.000200	0.		
10, 000	40, 000	.001100	.000100	0.		
10, 250	41, 000	.001100	0.			
10, 500	42, 000	.001150	.000050			
10, 750	43, 000	.001150	0.			
11, 000	44, 000	.001200	.000050			
11, 250	45, 000	.001250	.000050	.000100	.000100	
11, 500	46, 000	.001300	.000050			
11, 750	47, 000	.001350	.000050			
12, 000	48, 000	.001400	.000050			
12, 250	49, 000	.001450	.000050			
12, 500	50, 000	.001500	.000050	.000100	0.	
12, 750	51, 000	.001600	.000100			
13, 000	52, 000	.001650	.000050			
13, 250	53, 000	.001700	.000050			
13, 500	54, 000	.001750	.000050			
13, 750	55, 000	.001800	.000050	.000300	.000200	Elastic limit.
14, 000	56, 000	.002100	.000300			
14, 250	57, 000	.002250	.000150			
14, 500	58, 000	.002350	.000100			
14, 750	59, 000	.002500	.000150			
15, 000	60, 000	.003100	.000600	.001300	.001000	
15, 250	61, 000	.003500	.000400			
15, 500	62, 000	.004000	.000500			
15, 750	63, 000	.004550	.000550			
16, 000	64, 000	.005450	.000900			
16, 250	65, 000	.005950	.000500	.003850	.002550	
16, 500	66, 000	.006950	.001000			
16, 750	67, 000	.007550	.000600			
17, 000	68, 000	.008600	.001050			
17, 250	69, 000	.009350	.000750			
17, 500	70, 000	.010450	.001100	.007850	.004000	
18, 000	72, 000	.012150	.001700			
18, 500	74, 000	.014000	.001850			
19, 000	76, 000	.016250	.002250			
19, 500	78, 000	.018250	.002000			
20, 000	80, 000	.020600	.002350			
20, 500	82, 000	.022600	.002000			
21, 000	84, 000	.025600	.003000			
21, 500	86, 000	.028150	.002550			
22, 000	88, 000	.030700	.002550			
22, 500	90, 000	.034600	.003900			
23, 000	92, 000	.038300	.003700			
23, 500	94, 000	.043200	.004900			
24, 000	96, 000	.048200	.005000			Micrometer removed.
24, 500	98, 000	.0525	.0043			
25, 000	100, 000	.0675	.0150			
25, 500	102, 000	.0750	.0075			
25, 960	103, 840	.0800	.0050			Ultimate strength.
23, 000						Load at time of rupture.

GENERAL SUMMARY.

Specific gravity	7. 8666
Hardness	25. 78
Tensile strength per square inch of original section ... pounds	103, 840
Elastic limit per square inch of original section ... do	55, 000
Elongation per inch after rupture ... inch	0. 1650
Elongation per inch under strain at elastic limit ... do	.0018
Reduction in diameter at point of rupture ... do	.094
Reduction in area after rupture, per centum of original section	30. 8
Position of rupture	.70 inch from neck.
Character of broken surface	fine granular, silvery luster; dull center.

No. 302.



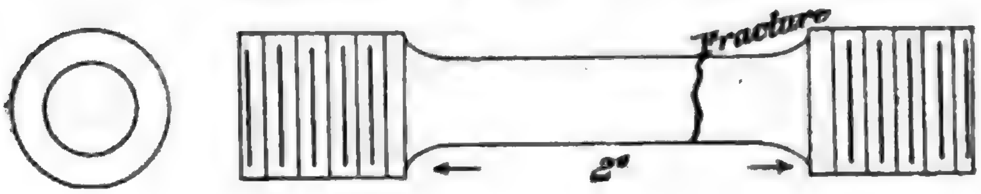
[Mark on bar, $\underset{5}{\text{W. T.}}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000050	.000050	0.		
2, 500	10, 000	.000250	.000200	0.		
3, 750	15, 000	.000400	.000150	0.		
5, 000	20, 000	.000600	.000200	0.		
6, 250	25, 000	.000700	.000100	0.		
7, 500	30, 000	.000900	.000200	0.		
8, 750	35, 000	.001050	.000150	0.		
10, 000	40, 000	.001250	.000200	0.		
10, 250	41, 000	.001250	0.			
10, 500	42, 000	.001300	.000050			
10, 750	43, 000	.001300	0.			
11, 000	44, 000	.001350	.000050			
11, 250	45, 000	.001400	.000050	.000050	.000050	
11, 500	46, 000	.001400	0.			
11, 750	47, 000	.001450	.000050			
12, 000	48, 000	.001500	.000050			
12, 250	49, 000	.001550	.000050			
12, 500	50, 000	.001600	.000050	.000150	.000100	
12, 750	51, 000	.001750	.000150			
13, 000	52, 000	.001850	.000100			
13, 250	53, 000	.001950	.000100			Elastic limit.
13, 500	54, 000	.002200	.000250			
13, 750	55, 000	.002350	.000150	.000650	.000500	
14, 000	56, 000	.002700	.000350			
14, 250	57, 000	.003200	.000500			
14, 500	58, 000	.003700	.000500			
14, 750	59, 000	.004250	.000550			
15, 000	60, 000	.005000	.000750	.003000	.002350	
15, 250	61, 000	.005700	.000700			
15, 500	62, 000	.006500	.000800			
15, 750	63, 000	.007100	.000600			
16, 000	64, 000	.008450	.001350			
16, 250	65, 000	.009000	.000550	.006550	.003550	
16, 500	66, 000	.009650	.000650			
16, 750	67, 000	.010250	.000600			
17, 000	68, 000	.011650	.001400			
17, 250	69, 000	.012250	.000600			
17, 500	70, 000	.013550	.001300	.010850	.004300	
18, 000	72, 000	.015100	.001550			
18, 500	74, 000	.017450	.002350			
19, 000	76, 000	.019800	.002350			
19, 500	78, 000	.022050	.002250			
20, 000	80, 000	.024600	.002550			
20, 500	82, 000	.027650	.003050			
21, 000	84, 000	.030550	.002900			
21, 500	86, 000	.033600	.003050			
22, 000	88, 000	.037100	.003500			
22, 500	90, 000	.043250	.006150			
23, 000	92, 000	.047550	.004300			Micrometer removed.
23, 500	94, 000	.053550	.006000			
24, 000	96, 000	.0600	.006450			
24, 500	98, 000	.0750	.0150			
25, 000	100, 000	.1000	.0250			
25, 070	100, 280	.1350	.0350			Ultimate strength.
22, 900						Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	100, 280
Elastic limit per square inch of original section	do.	53, 000
Elongation per inch after rupture	inch	0. 16750
Elongation per inch under strain at elastic limit	do.	.00195
Reduction in diameter at point of rupture	do.	.104
Reduction in area after rupture, per centum of original section		33. 6
Position of rupture		.70 inch from neck.
Character of broken surface		fine granular silvery luster, dull center.

No. 303.



[Mark on bar, W.$_6$T.; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000250	.000150	0.	....	
3, 750	15, 000	.000400	.000150	0.	....	
5, 000	20, 000	.000650	.000250	0.	....	
6, 250	25, 000	.000800	.000150	0.	....	
7, 500	30, 000	.001000	.000200	0.	....	
8, 750	35, 000	.001100	.000100	.000050	.000050	
10, 000	40, 000	.001300	.000200	.000050	0.	
10, 250	41, 000	.001300	.0	....	....	
10, 500	42, 000	.001350	.000050	....	....	
10, 750	43, 000	.001400	.000050	....	....	
11, 000	44, 000	.001450	.000050	....	....	
11, 250	45, 000	.001500	.000050	.000050	0.	
11, 500	46, 000	.001550	.000050	....	....	
11, 750	47, 000	.001600	.000050	....	....	
12, 000	48, 000	.001650	.000050	....	....	
12, 250	49, 000	.001700	.000050	....	....	
12, 500	50, 000	.001750	.000050	.000200	.000150	
12, 750	51, 000	.001800	.000050	....	....	
13, 000	52, 000	.001850	.000050	....	....	
13, 250	53, 000	.001900	.000050	....	....	Elastic limit.
13, 500	54, 000	.002050	.000100	....	....	
13, 750	55, 000	.002350	.000300	.000600	.000400	
14, 000	56, 000	.002650	.000300	....	....	
14, 250	57, 000	.002950	.000300	....	....	
14, 500	58, 000	.003450	.000500	....	....	
14, 750	59, 000	.003950	.000500	....	....	
15, 000	60, 000	.004550	.000600	.002000	.002000	
15, 250	61, 000	.005400	.000850	....	....	
15, 500	62, 000	.005950	.000550	....	....	
15, 750	63, 000	.006650	.000700	....	....	
16, 000	64, 000	.007700	.001050	....	....	
16, 250	65, 000	.008350	.000650	.006000	.004000	
16, 500	66, 000	.009300	.000950	....	....	
16, 750	67, 000	.009900	.000600	....	....	
17, 000	68, 000	.011050	.001150	....	....	
17, 250	69, 000	.011750	.000700	....	....	
17, 500	70, 000	.012900	.001150	.010250	.004250	
18, 000	72, 000	.014800	.001900	....	....	
18, 500	74, 000	.016900	.002100	....	....	
19, 000	76, 000	.019000	.002100	....	....	
19, 500	78, 000	.021450	.002450	....	....	
20, 000	80, 000	.023700	.002250	....	....	
20, 500	82, 000	.026450	.002750	....	....	
21, 000	84, 000	.029550	.003100	....	....	
21, 500	86, 000	.032750	.003200	....	....	
22, 000	88, 000	.036450	.003700	....	....	
22, 500	90, 000	.039950	.003500	....	....	
23, 000	92, 000	.045450	.005500	....	....	
23, 500	94, 000	.051450	.006000	....	....	Micrometer removed.
24, 000	96, 000	.0600	.008550	....	....	
24, 500	98, 000	.0700	.0100	....	....	
25, 000	100, 000	.0900	.0200	....	....	
25, 110	100, 440	.1150	.0250	....	....	Ultimate strength.
23, 300	....	....	....	....	....	Load at time of rupture.

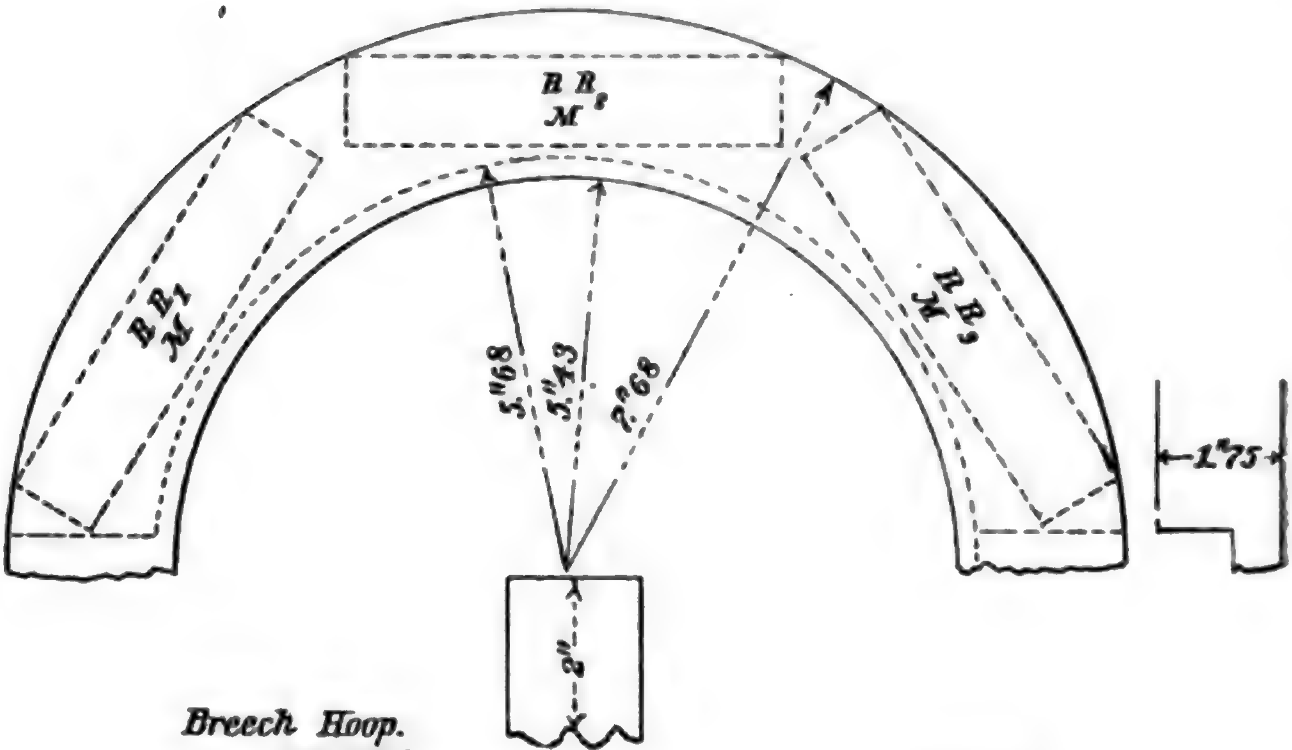
GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	100,440
Elastic limit per square inch of original section	do	53,000
Elongation per inch after rupture	inch..	0.1625
Elongation per inch under strain at elastic limit	do....	.0019
Reduction in diameter at point of rupture	do....	.104
Reduction in area after rupture, per centum of original section		33.6
Position of rupture		one-half inch from neck.
Character of broken surface		fine granular silvery luster, dull center

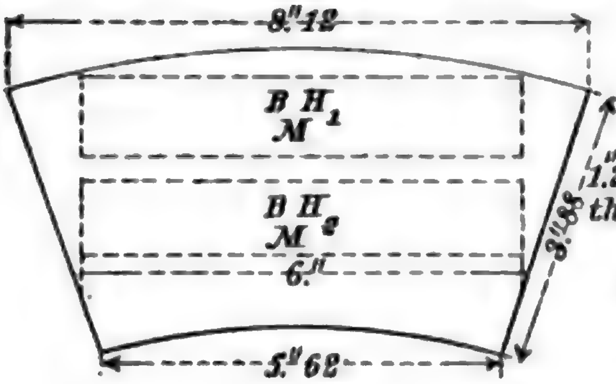
TESTS BY TENSION: EIGHT STEEL SPECIMENS FROM FORGES FOR MANN GUN.

August 19, 1884.

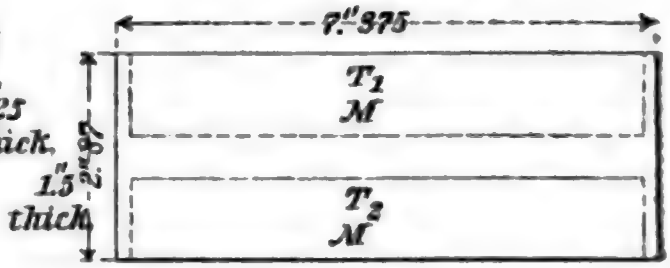
Retaining Ring.



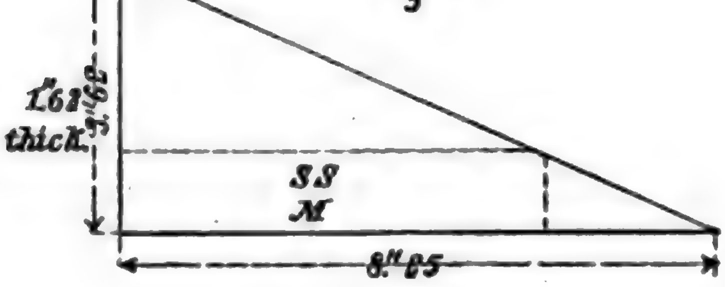
Breech Hoop.
marked 2037.



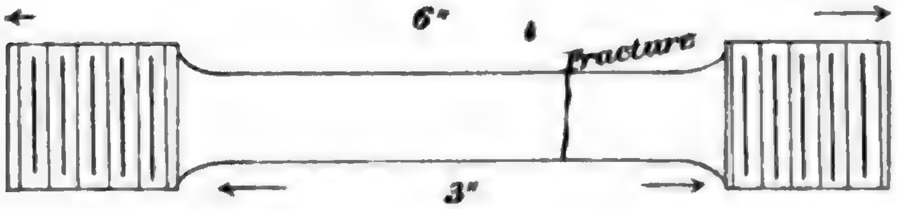
Transom.
marked 2028.



Side Straps.
marked 2028.
3



No. 394.



[Marks on bar, B. H. M.: diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000133	.000133	0.	....	
2,500	10,000	.000267	.000134	0.	....	
3,750	15,000	.000400	.000133	0.	....	
5,000	20,000	.000567	.000167	0.	....	
6,250	25,000	.000733	.000166	0.	....	
7,500	30,000	.000933	.000200	0.	....	
7,750	31,000	.000967	.000034	....	....	
8,000	32,000	.001000	.000033	....	....	
8,250	33,000	.001000	0.	....	....	
8,500	34,000	.001033	.000033	....	....	
8,750	35,000	.001067	.000034	0.	....	
9,000	36,000	.001133	.000066	....	....	
9,250	37,000	.001167	.000034	....	....	
9,500	38,000	.001200	.000033	....	....	
9,750	39,000	.001233	.000033	....	....	
10,000	40,000	.001267	.000034	0.	....	
10,250	41,000	.001300	.000033	....	....	
10,500	42,000	.001333	.000033	....	....	
10,750	43,000	.001367	.000034	....	....	
11,000	44,000	.001400	.000033	....	....	
11,250	45,000	.001400	0.	.000033	.000033	
11,500	46,000	.001433	.000033	....	....	
11,750	47,000	.001467	.000034	....	....	
12,000	48,000	.001500	.000033	....	....	
12,250	49,000	.001533	.000033	....	....	
12,500	50,000	.001600	.000067	.000033	0.	
12,750	51,000	.001633	.000033	....	....	
13,000	52,000	.001667	.000034	....	....	
13,250	53,000	.001700	.000033	....	....	
13,500	54,000	.001733	.000033	....	....	
13,750	55,000	.001767	.000034	.000067	.000034	
14,000	56,000	.001800	.000033	....	....	
14,250	57,000	.001833	.000033	....	....	
14,500	58,000	.001900	.000067	....	....	
14,750	59,000	.001933	.000033	....	....	
15,000	60,000	.002033	.000100	.000067	0.	
15,250	61,000	.002067	.000034	....	....	Elastic limit.

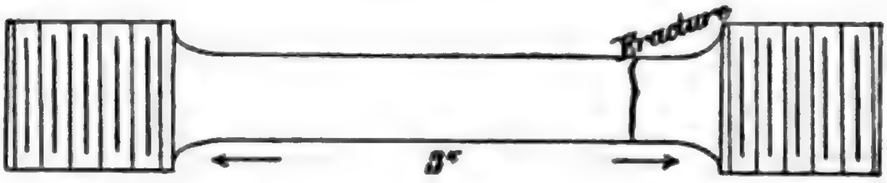
The tensile stress fell 4,000 pounds per square inch, while the elongation increased .0022 inch per inch.

14,250	57,000	.004267	.002200	....	....	
14,500	58,000	.006767	.002500	....	....	
14,750	59,000	.012300	.005533	....	....	
15,000	60,000	.012333	.000033	....	....	
15,250	61,000	.012700	.000367	....	....	
15,500	62,000	.013967	.001267	....	....	
15,750	63,000	.015033	.001066	....	....	
16,000	64,000	.015767	.000734	....	....	
16,250	65,000	.016900	.001133	.014267	.014200	
16,500	66,000	.018367	.001467	....	....	
16,750	67,000	.019267	.000900	....	....	
17,000	68,000	.020733	.001466	....	....	
17,250	69,000	.021733	.001000	....	....	
17,500	70,000	.023667	.001934	.020733	.006466	
18,000	72,000	.025967	.002300	....	....	
18,500	74,000	.029667	.003700	....	....	
19,000	76,000	.033500	.003833	....	....	
19,500	78,000	.037333	.003833	....	....	
20,000	80,000	.042333	.005000	....	....	
20,500	82,000	.051700	.009367	....	....	
21,000	84,000	.055700	.004000	....	....	
21,500	86,000	.066667	.010967	....	....	Micrometer removed.
22,000	88,000	.0833	.016633	....	....	
22,500	90,000	.1133	.0300	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity	7.8643
Hardness	20.50
Tensile strength per square inch of original section ..pounds..	90,000
Elastic limit per square inch of original section ..do...	61,000
Elongation per inch after rupture ..inch..	0.15
Elongation per inch under strain at elastic limit ..do ..	.002067
Reduction in diameter at point of rupture ..do...	.084
Reduction in area after rupture, per centum of original section	27.6
Position of rupture	.75 inch from neck.
Character of broken surface	silky; contains spots of different colors; fractured obliquely.
Elongation of inch sections	.11 inch, .13 inch (.21 inch fractured section).

No. 395.



[Marks on bar $\overset{\text{B. H.}}{\text{M.}}$ 2; diameter, .564 inch; sectional area, .25 square inch.]

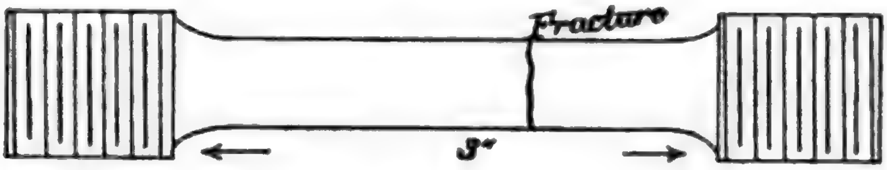
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000133	.000133	0.	....	
2,500	10,000	.000233	.000100	0.	....	
3,750	15,000	.000367	.000134	0.	....	
5,000	20,000	.000567	.000200	0.	....	
6,250	25,000	.000733	.000166	0.	....	
7,500	30,000	.000900	.000167	0.	....	
7,750	31,000	.000933	.000033	....	....	
8,000	32,000	.000967	.000034	....	....	
8,250	33,000	.000967	0.	....	....	
8,500	34,000	.001000	.000033	....	....	
8,750	35,000	.001033	.000033	0.	....	
9,000	36,000	.001067	.000034	....	....	
9,250	37,000	.001100	.000033	....	....	
9,500	38,000	.001133	.000033	....	....	
9,750	39,000	.001167	.000034	....	....	
10,000	40,000	.001200	.000033	0.	....	
10,250	41,000	.001233	.000033	....	....	
10,500	42,000	.001267	.000034	....	....	
10,750	43,000	.001300	.000033	....	....	
11,000	44,000	.001333	.000033	....	....	
11,250	45,000	.001367	.000034	0.	....	
11,500	46,000	.001400	.000033	....	....	
11,750	47,000	.001433	.000033	....	....	
12,000	48,000	.001467	.000034	....	....	
12,250	49,000	.001500	.000033	....	....	
12,500	50,000	.001533	.000033	.000033	.000033	
12,750	51,000	.001600	.000067	....	....	
13,000	52,000	.001633	.000033	....	....	
13,250	53,000	.001667	.000034	....	....	
13,500	54,000	.001700	.000033	....	....	
13,750	55,000	.001733	.000033	.000033	0.	
14,000	56,000	.001833	.000100	....	....	
14,250	57.000	.001900	.000067	....	....	Elastic limit.
The tensile stress fell 4,000 pounds per square inch, while the elongation increased .0048 inch per inch.						
13,250	53,000	.006700	.004800	....	....	
13,500	54,000	.010000	.003300	....	....	
13,750	55,000	.010667	.000667	....	....	
14,000	56,000	.011633	.000966	....	....	
14,250	57,000	.012367	.000734	....	....	
14,500	58,000	.013500	.001133	....	....	
14,750	59,000	.014167	.000667	....	....	
5,000	60,000	.015667	.001500	.013300	.013267	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
15, 250	61, 000	. 016567	. 000900	....	....	
15, 500	62, 000	. 017367	. 000800	....	....	
15, 750	63, 000	. 018600	. 001233	....	....	
16, 000	64. 000	. 020167	. 001567	....	....	
16, 250	65, 000	. 021933	. 001766	. 010167	. 005867	
16, 500	66, 000	. 023067	. 001134	....	....	
16, 750	67, 000	. 024000	. 000933	....	....	
17, 000	68, 000	. 026000	. 002000	....	....	
17, 250	69, 000	. 027400	. 001400	....	....	
17, 500	70, 000	. 029467	. 002067	. 026567	. 007400	
18, 000	72, 000	. 033000	. 003533	....	....	
18, 500	74, 000	. 037333	. 004333	....	....	
19, 000	76, 000	. 042167	. 004834	....	....	
19, 500	78, 000	. 048267	. 006100	....	....	
20, 000	80, 000	. 057267	. 009000	....	....	Micrometer removed.
20, 500	82, 000	. 0667	. 009433	....	....	
21, 000	84, 000	. 0833	. 0166	....	....	
21, 500	86, 000	. 1100	. 0267	....	....	
21, 780	87, 120	. 1567	. 0467	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	87, 120
Elastic limit per square inch of original section	do...	57, 000
Elongation per inch after rupture	inch..	0. 19
Elongation per inch under strain at elastic limit	do...	.001900
Reduction in diameter at point of rupture	do...	.094
Reduction in area after rupture, per centum of original section		30. 6
Position of rupture		.25 inch from neck; oblique fracture.
Character of broken surface		silky; contains spots of different colors.
Elongation of inch sections		.15-inch, .16-inch (.26-inch fractured section).

No. 396.



[Marks on bar, R. R.$_1$; diameter, .564 inch; sectional area, .25 square inch.]

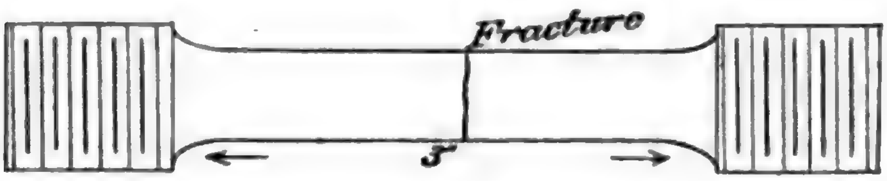
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	. 000067	. 000067	0.	....	
2, 500	10, 000	. 000200	. 000133	0.	....	
3, 750	15, 000	. 000367	. 000167	0.	....	
5, 000	20, 000	. 000533	. 000166	0.	....	
6, 250	25, 000	. 000667	. 000134	0.	....	
7, 500	30, 000	. 000867	. 000200	0.	....	
7, 750	31, 000	. 000900	. 000033	....	....	
8, 000	32, 000	. 000933	. 000033	....	....	
8, 250	33, 000	. 000967	. 000034	....	....	
8, 500	34, 000	. 001000	. 000033	....	....	
8, 750	35, 000	. 001033	. 000033	0.	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
9, 000	36, 000	.001067	.000034	....	....	
9, 250	37, 000	.001100	.000033	....	....	
9, 500	38, 000	.001133	.000033	....	....	
9, 750	39, 000	.001167	.000034	....	....	
10, 000	40, 000	.001233	.000066	0.	....	Elastic limit.
10, 250	41, 000	.005667	.004434	....	....	
10, 500	42, 000	.008933	.003266	....	....	
10, 750	43, 000	.008967	.000034	....	....	
11, 000	44, 000	.009000	.000033	....	....	
11, 250	45, 000	.009033	.000033	.007300	.007300	
11, 500	46, 000	.009300	.000267	....	....	
11, 750	47 000	.009567	.000267	....	....	
12, 000	48, 000	.010233	.000666	....	....	
12, 250	49, 000	.010967	.000734	....	....	
12, 500	50, 000	.012233	.001266	.010333	.003033	
12, 750	51, 000	.012667	.000434	....	....	
13, 000	52, 000	.013667	.001000	....	....	
13, 250	53, 000	.014367	.000700	....	....	
13, 500	54, 000	.015433	.001066	....	....	
13, 750	55, 000	.016367	.000934	.014133	.003800	
14, 000	56, 000	.017767	.001400	....	....	
14, 250	57, 000	.018400	.000633	....	....	
14, 500	58, 000	.020100	.001700	....	....	
14, 750	59, 000	.021333	.001233	....	....	
15, 000	60, 000	.022600	.001267	.020067	.005934	
15, 500	62, 000	.024500	.001900	....	....	
16, 000	64, 000	.027000	.002500	....	....	
16, 500	66, 000	.030000	.003000	....	....	
17, 000	68, 000	.033000	.003000	....	....	
17, 500	70, 000	.037533	.004533	....	....	
18, 000	72, 000	.042000	.004467	....	....	
18, 500	74, 000	.045267	.003267	....	....	
19, 000	76, 000	.050667	.005400	....	....	
19, 500	78, 000	.057067	.006400	....	....	
20, 000	80, 000	.064667	.007600	....	....	Micrometer removed.
20, 500	82, 000	.0767	.012033	....	....	
21, 000	84, 000	.0967	.0200	....	....	
21, 500	86, 000	.1200	.0233	....	....	
21, 680	86, 720	.1733	.0533	....	....	Ultimate strength.
19, 500	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength, per square inch of original section	pounds..	86, 720
Elastic limit, per square inch of original section	do....	40, 000
Elongation per inch after rupture	inch..	0. 24
Elongation per inch under strain at elastic limit	do...	.001233
Reduction in diameter at point of rupture	do ...	.134
Reduction in area after rupture, per centum of original section		41. 9
Position of rupture		1.05 inches from neck.
Character of broken surface		dull silky, 40 per cent.; fine granular, 60 per cent. The bar parted first in the silky section.
Elongation of inch sections		.15 inch .24 inch (.33 inch fractured section).

No. 397.



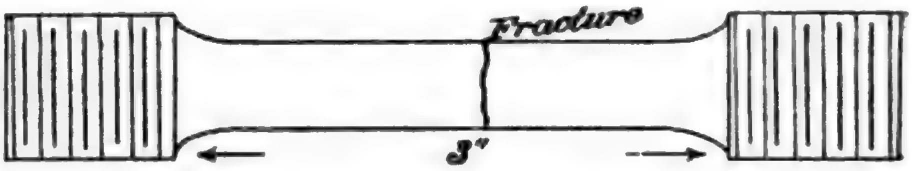
[Marks on bar, $\frac{\text{R. R.}_2}{\text{M.}}$; diameter, .564 inch; sectional area, .25 inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000067	.000067	0.		
2,500	10,000	.000233	.000166	0.		
3,750	15,000	.000400	.000167	0.		
5,000	20,000	.000567	.000167	0.		
6,250	25,000	.000733	.000166	0.		
7,500	30,000	.000900	.000167	0.		
7,750	31,000	.000933	.000033			
8,000	32,000	.000967	.000034			
8,250	33,000	.001000	.000033			
8,500	34,000	.001033	.000033			
8,750	35,000	.001067	.000034	0.		
9,000	36,000	.001100	.000033			
9,250	37,000	.001133	.000033			
9,500	38,000	.001200	.000067			
9,750	39,000	.001233	.000033			
10,000	40,000	.001300 .005267	.000067 .003967	 .003867	 .003867	Elastic limit.
10,250	41,000	.005633	.000366			
10,500	42,000	.005967	.000334			
10,750	43,000	.006433	.000466			
11,000	44,000	.007267	.000834			
11,250	45,000	.008033	.000766	.006433	.002566	
11,500	46,000	.008900	.000867			
11,750	47,000	.009433	.000533			
12,000	48,000	.010400	.000967			
12,250	49,000	.011000	.000600			
12,500	50,000	.011900	.000900	.010000	.003567	
12,750	51,000	.012700	.000800			
13,000	52,000	.013433	.000733			
13,250	53,000	.014500	.001067			
13,500	54,000	.015600	.001100			
13,750	55,000	.016433	.000833	.014133	.004133	
14,000	56,000	.017600	.001167			
14,250	57,000	.018367	.000767			
14,500	58,000	.019500	.001133			
14,750	59,000	.020600	.001100			
15,000	60,000	.022100	.001500	019600	.005467	
15,500	62,000	.024067	.001967			
16,000	64,000	.026767	.002700			
16,500	66,000	.029767	.003900			
17,000	68,000	.032967	.003200			
17,500	70,000	.036000	.003033			
18,000	72,000	.040000	.004000			
18,500	74,000	.044167	.004167			
19,000	76,000	.049333	.005166			
19,500	78,000	.056000	.006667			
20,000	80,000	.064000	.008000			Micrometer removed.
20,500	82,000	.0733	.0093			
21,000	84,000	.0867	.0134			
21,500	86,000	.1100	.0233			
21,750	87,000	.1700	.0600			Ultimate strength.
20,000						Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		7.8654
Hardness		15.35
Tensile strength, per square inch of original section	pounds..	87,000
Elastic limit, per square inch of original section	do...	40,000
Elongation per inch after rupture	inch..	0.2333
Elongation per inch under strain at elastic limit	do...	.001300
Reduction in diameter at point of rupture	do...	.104
Reduction in area after rupture, per centum of original section		32.5
Position of rupture,		1.35 inches from neck.
Character of broken surface		fine granular, radiating from a dull silky spot at circumference.
Elongation of inch section		.17 inch (.32 inch fractured section), .21 inch.

No. 398.



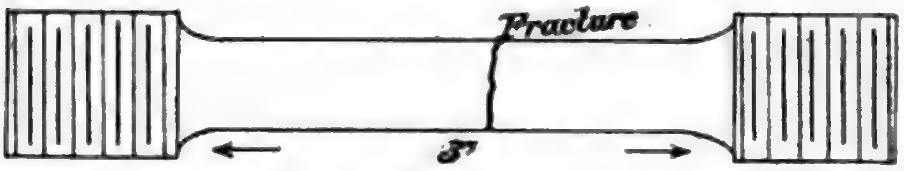
[Marks on bar, $\frac{\text{R. R.}}{\text{M.}}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	. 000067	. 000067	0.	....	
2, 500	10, 000	. 000200	. 000133	0.	....	
3, 750	15, 000	. 000333	. 000133	0.	....	
5, 000	20, 000	. 000467	. 000134	0.	....	
6, 250	25, 000	. 000667	. 000200	0.	....	
7, 500	30, 000	. 000800	. 000133	0.	....	
7, 750	31, 000	. 000867	. 000067	....	....	
8, 000	32, 000	. 000900	. 000033	....	....	
8, 250	33, 000	. 000933	. 000033	....	....	
8, 500	34, 000	. 000967	. 000034	....	....	
8, 750	35, 000	. 001000	. 000033	0.	....	
9, 000	36, 000	. 001033	. 000033	....	....	
9, 250	37, 000	. 001067	. 000034	....	....	
9, 500	38, 000	. 001100	. 000033	....	....	
9, 750	39, 000	. 001167	. 000067	....	....	Elastic limit.
10, 000	40, 000	. 001200	. 000033	0.	....	
10, 250	41, 000	. 004667	. 003467	....	....	
10, 500	42, 000	. 006000	. 001333	....	....	
10, 750	43, 000	. 006833	. 000833	....	....	
11, 000	44, 000	. 007100	. 000267	....	....	
11, 250	45, 000	. 007767	. 000667	. 006000	. 006000	
11, 500	46, 000	. 008367	. 000600	....	....	
11, 750	47, 000	. 009267	. 000900	....	....	
12, 000	48, 000	. 010000	. 000733	....	....	
12, 250	49, 000	. 010733	. 000733	....	....	
12, 500	50, 000	. 011700	. 000967	. 009800	. 003800	
12, 750	51, 000	. 012333	. 000633	....	....	
13, 000	52, 000	. 013233	. 000900	....	....	
13, 250	53, 000	. 014000	. 000767	....	....	
13, 500	54, 000	. 015233	. 001233	....	....	
13, 750	55, 000	. 015933	. 000700	. 013733	. 003933	
14, 000	56, 000	. 017000	. 001067	....	....	
14, 250	57, 000	. 017733	. 000733	....	....	
14, 500	58, 000	. 019033	. 001300	....	....	
14, 750	59, 000	. 020200	. 001167	....	....	
15, 000	60, 000	. 021667	. 001467	. 019167	. 005434	
15, 500	62, 000	. 023867	. 002200	....	....	
16, 000	64, 000	. 026433	. 002566	....	....	
16, 500	66, 000	. 029033	. 002600	....	....	
17, 000	68, 000	. 032967	. 003934	....	....	
17, 500	70, 000	. 035667	. 002700	....	....	
18, 000	72, 000	. 039267	. 003600	....	....	
18, 500	74, 000	. 044133	. 004866	....	....	
19, 000	76, 000	. 049667	. 005534	....	....	
19, 500	78, 000	. 055333	. 005666	....	....	
20, 000	80, 000	. 062333	. 007000	....	....	Micrometer removed.
20, 500	82, 000	. 0767	. 014367	....	....	
21, 000	84, 000	. 0867	. 0100	....	....	
21, 500	86, 000	. 1133	. 0266	....	....	
21, 860	87, 440	. 1667	. 0534	....	....	Ultimate strength.
19, 500	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	87, 440
Elastic limit per square inch of original section	do....	40, 000
Elongation per inch after rupture	inch..	0. 25
Elongation per inch under strain at elastic limit	do....	. 001200
Reduction in diameter at point of rupture	do....	. 124
Reduction in area after rupture, per centum of original section		39. 2
Position of rupture		.25 inch from middle of stem.
Character of broken surface		dull silky, 90 per cent., granular, 10 per cent., oblique fracture.
Elongation of inch sections		.17 inch (.37 inch fractured section) .21 inch

No. 399.



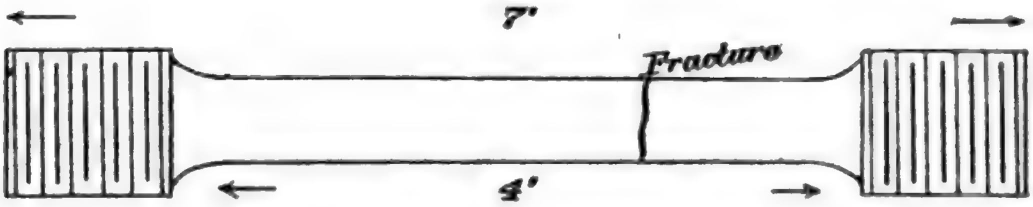
[Marks on bar, $\frac{\text{S. S.}}{\text{M.}}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000067	.000067	0.	....	
2, 500	10, 000	.000233	.000166	0.	....	
3, 750	15, 000	.000367	.000134	0.	....	
5, 000	20, 000	.000533	.000166	0.	....	
6, 250	25, 000	.000700	.000167	0.	....	
7, 500	30, 000	.000867	.000167	0.	....	
7, 750	31, 000	.000867	0.	....	....	
8, 000	32, 000	.000900	.000033	....	....	
8, 250	33, 000	.000933	.000033	....	....	
8, 500	34, 000	.000967	.000034	....	....	
8, 750	35, 000	.001000	.000033	0.	....	
9, 000	36, 000	.001033	.000033	....	....	
9, 250	37, 000	.001067	.000034	....	....	
9, 500	38, 000	.001100	.000033	....	....	
9, 750	39, 000	.001133	.000033	....	....	
10, 000	40, 000	.001167	.000034	0.	....	
10, 250	41, 000	.001200	.000033	....	....	
10, 500	42, 000	.001233	.000033	....	....	
10, 750	43, 000	.001267	.000034	....	....	
11, 000	44, 000	.001300	.000033	....	....	
11, 250	45, 000	.001333	.000033	0.	....	
11, 500	46, 000	.001367	.000034	....	....	
11, 750	47, 000	.001400	.000033	....	....	
12, 000	48, 000	.001433	.000033	....	....	
12, 250	49, 000	.001467	.000034	....	....	
12, 500	50, 000	.001500	.000033	.000033	.000033	
12, 750	51, 000	.001567	.000067	....	....	
13, 000	52, 000	.001633	.000066	....	....	
13, 250	53, 000	.001700	.000067	....	....	Elastic limit.
13, 500	54, 000	.004067	.002367	....	....	
13, 750	55, 000	.006400	.002338	.004567	.004534	
14, 000	56, 000	.007733	.001333	....	....	
14, 250	57, 000	.008600	.000867	....	....	
14, 500	58, 000	.009900	.001300	....	....	
14, 750	59, 000	.011067	.001167	....	....	
15, 000	60, 000	.012100	.001033	.009833	.005266	
15, 500	62, 000	.013600	.001500	....	....	
16, 000	64, 000	.015000	.001400	....	....	
16, 500	66, 000	.017000	.002000	....	....	
17, 000	68, 000	.020000	.003000	....	....	
17, 500	70, 000	.022333	.002333	....	....	
18, 000	72, 000	.024667	.002334	....	....	
18, 500	74, 000	.027400	.002733	....	....	
19, 000	76, 000	.030600	.003200	....	....	
19, 500	78, 000	.034000	.003400	....	....	
20, 000	80, 000	.038000	.004000	....	....	
20, 500	82, 000	.043033	.005033	....	....	
21, 000	84, 000	.048000	.004967	....	....	Micrometer removed.
21, 500	86, 000	.0533	.0053	....	....	
22, 000	88, 000	.0667	.0134	....	....	
22, 500	90, 000	.0767	.0100	....	....	
23, 000	92, 000	.0967	.0200	....	....	
23, 380	93, 520	.1400	.0433	....	....	Ultimate strength.
19, 900	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		7. 8640
Hardness		20. 03
Tensile strength per square inch of original section	pounds..	93, 520
Elastic limit per square inch of original section	do....	53, 000
Elongation per inch after rupture	inch..	0. 2267
Elongation per inch under strain at elastic limit	do....	.001700
Reduction in diameter at point of rupture	do....	.174
Reduction in area after rupture, per centum of original section		52. 2
Position of rupture		1.40 inches from neck.
Character of broken surface		fine silky; cup-shaped ends.
Elongation of inch sections		.10 inch (.37 inch fractured section), .21 inch.

No. 400.



[Marks on bar, $\frac{\text{T.}}{\text{M.}}$; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000150	.000150	0.	....	
2, 500	10, 000	.000325	.000175	.000025	.000025	
3, 750	15, 000	.000475	.000150	.000025	0.	
5, 000	20, 000	.000650	.000175	.000050	.000025	
6, 250	25, 000	000825	.000175	.000075	.000025	
7, 500	30, 000	.000950	.000125	.000075	0.	
7, 750	31, 000	.001025	.000075	....	....	
8, 000	32, 000	.001050	.000025	....	....	
8, 250	33, 000	.001075	.000025	....	....	
8, 500	34, 000	.001125	.000050	....	....	
8, 750	35, 000	.001150	.000025	.000075	0.	
9, 000	36, 000	.001200	.000050	....	....	
9, 250	37, 000	.001225	.000025	....	....	
9, 500	38, 000	.001250	.000025	....	....	
9, 750	39, 000	.001275	.000025	....	....	
10, 000	40, 000	.001325	.000050	.000075	0.	
10, 250	41, 000	.001350	.000025	....	....	
10, 500	42, 000	.001375	.000025	....	....	
10, 750	43, 000	.001425	.000050	....	....	
11, 000	44, 000	.001450	.000025	....	....	
11, 250	45, 000	.001500	.000050	.000100	.000025	
11, 500	46, 000	.001550	.000050	....	....	
11, 750	47, 000	.001600	.000050	....	....	Elastic limit.
12, 000	48, 000	.001750	.000150	....	....	
12, 250	49, 000	.002000	.000250	....	....	
12, 500	50, 000	.002350	.000350	.000800	.000700	
12, 750	51, 000	.002725	.000375	....	....	
13, 000	52, 000	.003575	.000850	....	....	
13, 250	53, 000	.004650	.001075	....	....	
13, 500	54, 000	.008750	.004100	....	....	
13, 750	55, 000	.009450	.000700	.007450	.006650	
14, 000	56, 000	.010125	.000675	....	....	
14, 250	57, 000	.010725	.000600	....	....	
14, 500	58, 000	.011725	.001000	....	....	
14, 750	59, 000	.012300	.000575	....	....	
15, 000	60, 000	.013525	.001225	.011250	.003800	
15, 500	62, 000	.015300	.001775	....	....	
16, 000	64, 000	.017000	.001700	....	....	
16, 500	66, 000	.019375	.002375	....	....	
17, 000	68, 000	.022025	.002650	....	....	
17, 500	70, 000	.024300	.002275	....	....	
18, 000	72, 000	.027000	.002700	....	....	
18, 500	74, 000	.032025	.005025	....	....	
19, 000	76, 000	.033525	.001500	....	....	
19, 500	78, 000	.037500	.003975	....	....	
20, 000	80, 000	.044500	.007000	....	....	
20, 500	82, 000	.0500	.0055	....	....	Micrometer removed.
21, 000	84, 000	.0575	.0075	....	....	
21, 500	86, 000	.0650	.0075	....	....	
22, 000	88, 000	.0775	.0125	....	....	
22, 500	90, 000	.0950	.0175	....	....	
22, 920	91, 680	.1500	.0550	....	....	Ultimate strength.
18, 200	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		7. 8643
Hardness		21. 05
Tensile strength per square inch of original section	pounds..	91, 680
Elastic limit per square inch of original section	do...	47, 000
Elongation per inch after rupture	inch..	0. 2225
Elongation per inch under strain at elastic limit	do...	.001600
Reduction in diameter at point of rupture	do...	.194
Reduction in area after rupture, per centum of original section		57.0
Position of rupture		1. 20 inches from neck.
Character of broken surface		fine silky. Cup-shaped ends.
Elongation of inch sections		.12 inch, .15 inch, .26 inch (.36 inch fractured section).

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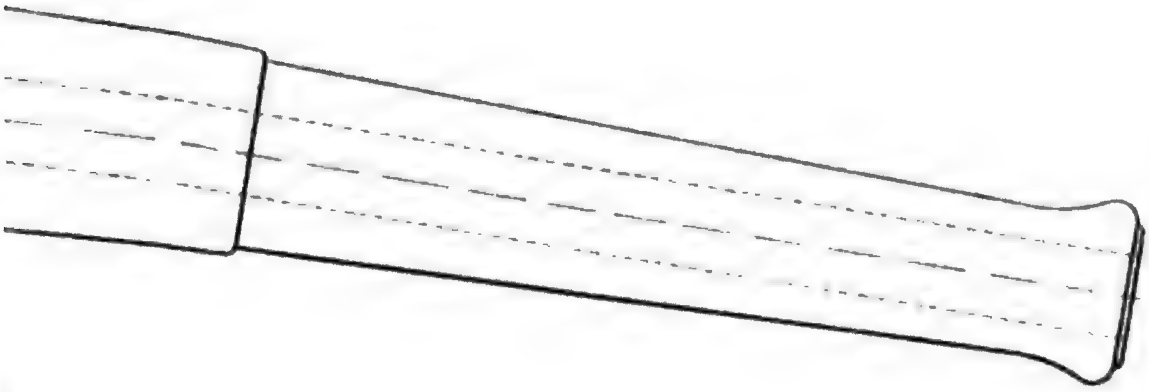

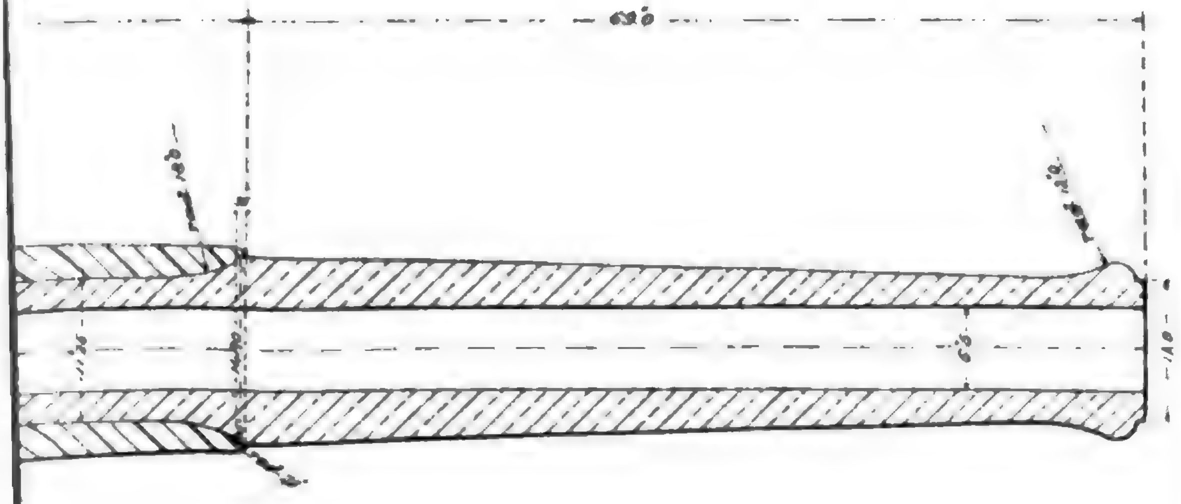

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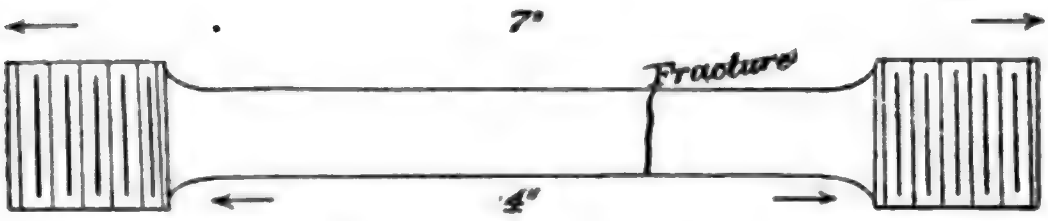
No. 401.



[Marks on bar, $\frac{T.}{M.}^{2}$; diameter, .564 inch; section area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000250	.000150	0.	....	
3, 750	15, 000	.000425	.000175	0.	....	
5, 000	20, 000	.000575	.000150	0.	....	
6, 250	25, 000	.000725	.000150	0.	....	
7, 500	30, 000	.000900	.000175	0.	....	
7, 750	31, 000	.000925	.000025	....	....	
8, 000	32, 000	.000950	.000025	....	....	
8, 250	33, 000	.000975	.000025	....	....	
8, 500	34, 000	.001000	.000025	....	....	
8, 750	35, 000	.001025	.000025	0.	....	
9, 000	36, 000	.001050	.000025	....	....	
9, 250	37, 000	.001075	.000025	....	....	
9, 500	38, 000	.001125	.000050	....	....	
9, 750	39, 000	.001150	.000025	....	....	
10, 000	40, 000	.001225	.000075	.000025	.000025	
10, 250	41, 000	.001250	.000025	....	....	
10, 500	42, 000	.001300	.000050	....	....	
10, 750	43, 000	.001325	.000025	....	....	
11, 000	44, 000	.001350	.000025	....	....	
11, 250	45, 000	.001400	.000050	.000025	0.	
11, 500	46, 000	.001425	.000025	....	....	
11, 750	47, 000	.001450	.000025	....	....	
12, 000	48, 000	.001500	.000050	....	....	
12, 250	49, 000	.001550	.000050	....	....	
12, 500	50, 000	.001575	.000025	.000050	.000025	
12, 750	51, 000	.001625	.000050	....	....	
13, 000	52, 000	.001675	.000050	....	....	
13, 250	53, 000	.001700	.000025	....	....	
13, 500	54, 000	.001775	.000075	....	....	
13, 750	55, 000	.001825	.000050	.000125	.000075	Elastic limit.
14, 000	56, 000	.009975	.008150	....	....	
14, 250	57, 000	.010700	.000725	....	....	
14, 500	58, 000	.011325	.000625	....	....	
14, 750	59, 000	.012200	.000875	....	....	
15, 000	60, 000	.013575	.001375	.011200	.011075	
15, 500	62, 000	.014825	.001250	....	....	
16, 000	64, 000	.016750	.001925	....	....	
16, 500	66, 000	.018600	.001850	....	....	
17, 000	68, 000	.021100	.002500	....	....	
17, 500	70, 000	.023750	.002650	....	....	
18, 000	72, 000	.026075	.002325	....	....	
18, 500	74, 000	.028800	.002725	....	....	
19, 000	76, 000	.032375	.003575	....	....	
19, 500	78, 000	.036075	.003700	....	....	
20, 000	80, 000	.040750	.004675	....	....	
20, 500	82, 000	.045500	.004750	....	....	
21, 000	84, 000	.052000	.006500	....	....	Micrometer removed.
21, 500	86, 000	.062500	.0105	....	....	
22, 000	88, 000	.072500	.0100	....	....	
22, 500	90, 000	.090000	.0175	....	....	
22, 960	91, 840	.147500	.0575	....	....	Ultimate strength.
18, 500	....	....	....	....	....	Load at time of rupture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	91, 840
Elastic limit per square inch of original section	do ..	55, 000
Elongation per inch after rupture	inch..	0. 24
Elongation per inch under strain at elastic limit	do...	.001825
Reduction in diameter at point of rupture	do...	.194
Reduction in area after rupture, per centum of original section		57. 0
Position of rupture		1. 20 inches from neck.
Character of broken surface		fine silky. Cup-shaped ends.
Elongation of inch sections		.13 inch, .20 inch, .27 inch (.36 inch, fractured section).

APPENDIX 26.

CONSTRUCTION REPORT OF AN 8-INCH RIFLE CONVERTED FROM A 10 INCH SMOOTH-BORE RODMAN GUN BY LINING WITH A STEEL TUBE.

BY LIEUT. H. D. BORUP, ORDNANCE DEPARTMENT.

(1 plate.)

The construction of this gun in its general features does not differ greatly from those hitherto made.

The principal point is the use of a steel tube, made from a solid forging, instead of one of coiled wrouhgt iron, simply, or in combination with steel.

THE CASING.

The piece selected for the casing was the 10-inch Rodman smooth-bore gun No. 113, and was prepared for the tube by boring to mean diameter of 12.999 inches, drilling the gas escape, recessing the muzzle, and cutting the screw for the retaining ring.

THE TUBE.

This was fabricated at the Midvale Steel Works, Nicetown, Pa., of open hearth steel, and was received here in the shape of a solid forging 126.75 inches long, by 14.5 inches in diameter; analysis showing it to contain—

Carbon	.39
Phosphorus	.026
Manganese	.896
Silicon	.146
Sulphur	.021

Mean of three tangential specimens taken from breech end, as determined at Watertown Arsenal:

Tenacity, pounds per square inch		79,400
Elongation after rupture	per cent..	22.6
Contraction of area	do....	30.2
Elastic limit, pounds per square inch		37,000

Breech cup.—A solid cylinder 8.7 inch long, and 8.65 inch, in diameter.

The muzzle collar was a hollow cylinder, rough finished to 7.1 inch, in length, 13.75 inches exterior, and 11.22 interior diameter.

Both collar and cup were taken from an ingot made for the Navy, of open hearth steel, by the Midvale Company, and as analyzed gave:

Carbon		.37
Phosphorus		.030
Manganese		.683
Silver		.137
Sulphur		.021
Before annealing, tenacity per square inch		77,570
Elongation after rupture	per cent..	13.5
Contraction of area	do....	13.2

After annealing these factors were 73,500, 27.5 per cent., 38 per cent.

The collar was not annealed; the cup was, and though no specimens were taken from either, their properties probably correspond to those of the ingot as above.

The material was of fine quality, and showed great resistance in working. The first hog-nose drill used in the boring broke and caused a delay of three days in removing.

After boring to proper size, the exterior was turned, and the cup, which in the mean time had been formed, was inserted. The fit was very close, two dog's-heads used in assembling being broken.

The tube was then rifled. The calipers and star gauge measurements showed a maximum play of but .005 inch between tube and casing throughout its entire length, except at the extreme breech.

Owing to the necessity of getting a proper contact at the base, while the difference of curvature of the rounded parts of the tube and casing was preserved, the tube had to be inserted and removed several times until it was obtained satisfactorily. Before the final insertion grooves were cut on the base of the cup, in order to allow any gas which might pass between the cup and tube to find its way to the open space formed by the surfaces of different curvatures above alluded to, and thence through the channel cut in the casing.

The parts were then assembled, the muzzle faced and grooved, holes for vent-bushing and securing pin formed, old vents filled with wrought-iron plugs, bushing and pin inserted, and gun finally inspected. The rifling not being deep enough, the piece was returned to the rifling machine to have this remedied. The work was inspected at all stages, and the principal dimensions determined. These will be found in the inspection report.

Record of measurements with star-gauge and calipers of 8-inch muzzle insertion gun No. 1.

Distance from muzzle.	Diameter of bore of casing.		Exterior diameter of tube.	Diameter of bore before proof.
	Horizontal.	Vertical.		
Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	....	....	11.489	8.002
2	....	....	11.489	8.001
3	....	....	11.489	8.001
4	....	....	11.489	8.002
5	12.999	12.999	....	8.003
6	12.999	12.999	12.994	8.004
7	12.999	12.998	12.994	8.005
8	12.999	12.998	12.994	8.006
9	12.9985	12.998	12.994	8.0065
10	12.999	12.998	12.994	8.007
11	12.999	12.998	12.994	8.008
12	12.999	12.998	12.994	8.008
13	12.999	12.999	12.994	8.008
14	12.999	12.998	12.994	8.008
15	12.999	12.999	12.994	8.008
16	12.999	12.998	12.994	8.0085
17	12.999	12.998	12.994	8.0085
18	12.999	12.998	12.994	8.009
19	12.999	12.998	12.994	8.0085
20	12.9985	12.999	12.994	8.008
21	12.9985	12.999	12.994	8.009
22	12.998	12.999	12.994	8.009
23	12.999	12.999	12.994	8.009
24	12.998	12.999	12.994	8.009
25	12.998	12.999	12.994	8.009
26	12.998	12.999	12.994	8.010
27	12.9975	12.998	12.994	8.010
28	12.9985	12.999	12.994	8.010
29	12.998	12.999	12.994	8.010
30	12.998	12.9985	12.994	8.010
31	12.998	12.9985	12.994	8.010
32	12.998	12.9985	12.994	8.010
33	12.998	12.9985	12.994	8.010
34	12.998	12.999	12.994	8.011
35	12.998	12.999	12.994	8.011
36	12.998	12.999	12.994	8.011
37	12.998	12.999	12.994	8.011
38	12.998	12.999	12.994	8.0115
39	12.998	12.999	12.994	8.012
40	12.998	12.999	12.994	8.012
41	12.998	12.999	12.994	8.012
42	12.999	12.998	12.994	8.012
43	12.999	12.998	12.994	8.012
44	12.999	12.999	12.994	8.012
45	12.999	12.999	12.994	8.012
46	12.999	12.999	12.994	8.012
47	12.999	12.999	12.994	8.012
48	12.999	12.999	12.994	8.014
49	12.999	12.999	12.994	8.014
50	12.9985	12.999	12.994	8.014
51	12.9985	12.999	12.994	8.014
52	12.9985	12.999	12.994	8.014

Records of measurements with star-gauge and calipers, &c.—Continued.

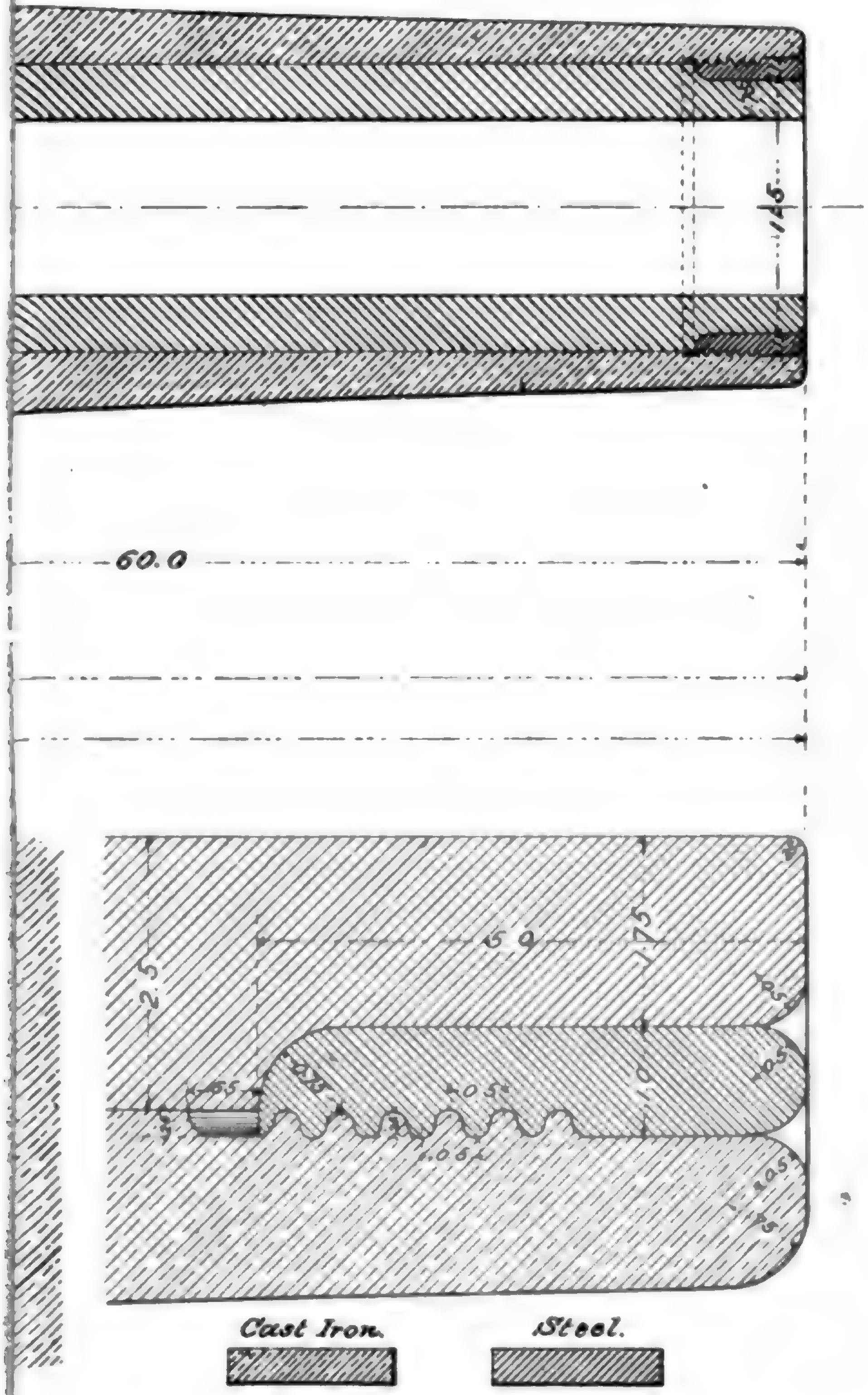
Distance from muzzle.	Diameter of bore of casting.		Exterior diameter of tube.	Diameter of bore before proof.	Distance from muzzle.	Diameter of bore of casting.		Exterior diameter of tube.	Diameter of bore before proof.
	Horizontal.	Vertical.				Horizontal.	Vertical.		
Inch.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
53	12.9985	12.999	12.994	8.014	88	12.998	12.998	12.994	8.016
54	12.9985	12.999	12.994	8.014	89	12.998	12.998	12.994	8.016
55	12.998	12.999	12.994	8.014	90	12.9985	12.998	12.994	8.016
56	12.999	12.9985	12.994	8.014	91	12.998	12.9975	12.994	8.016
57	12.998	12.999	12.994	8.014	92	12.998	12.998	12.994	8.016
58	12.998	12.9985	12.994	8.014	93	12.998	12.998	12.994	8.016
59	12.998	12.999	12.994	8.014	94	12.999	12.998	12.994	8.016
60	12.998	12.999	12.994	8.014	95	12.999	12.998	12.994	8.016
61	12.998	12.999	12.994	8.014	96	12.998	12.998	12.994	8.016
62	12.998	12.999	12.994	8.014	97	12.999	12.998	12.994	8.017
63	12.998	12.999	12.994	8.014	98	12.999	12.998	12.994	8.017
64	12.998	12.999	12.994	8.014	99	12.999	12.998	12.994	8.017
65	12.998	12.999	12.994	8.014	100	12.999	12.998	12.994	8.017
66	12.9985	12.999	12.994	8.014	101	12.999	12.999	12.994	8.017
67	12.999	12.999	12.994	8.014	102	12.999	12.999	12.994	8.017
68	12.999	12.999	12.994	8.014	103	12.999	12.9985	12.994	8.017
69	12.999	12.999	12.994	8.014	104	12.999	12.997	12.994	8.017
70	12.999	12.999	12.994	8.014	105	12.999	12.998	12.994	8.017
71	12.999	12.999	12.994	8.014	106	12.999	12.998	12.994	8.017
72	12.999	12.9985	12.994	8.014	107	12.999	12.998	12.994	8.018
73	12.999	12.999	12.994	8.0145	108	12.999	12.998	12.994	8.018
74	12.999	12.999	12.994	8.0145	109	12.998	12.998	12.994	8.018
75	12.999	12.999	12.994	8.0145	110	12.999	12.9975	12.993	8.0175
76	12.999	12.999	12.994	8.0145	111	12.998	12.997	12.993	8.017
77	12.999	12.999	12.994	8.014	112	12.998	12.997	12.993	8.018
78	12.999	12.9985	12.994	8.015	113	12.998	12.997	12.993	8.018
79	12.999	12.9985	12.994	8.015	114	12.998	12.997	12.993	8.019
80	12.999	12.9985	12.994	8.015	115	12.997	12.997	12.993	8.018
81	12.999	12.9985	12.994	8.015	116	12.997	12.997	12.992	8.018
82	12.999	12.9985	12.994	8.015	117	12.997	12.997	12.992	8.019
83	12.999	12.9985	12.994	8.015	118	13.000	13.001	12.992	8.020
84	12.999	12.998	12.994	8.016	119	....	....	....	8.020
85	12.999	12.998	12.994	8.016	120	....	....	....	8.021
86	12.9985	12.998	12.994	8.016	120½	....	....	....	8.022
87	12.998	12.996	12.994	8.016					

Distance from muzzle.	Diameter of bore across grooves.	Distance from muzzle.	Diameter of bore across grooves.
101	8.137	50	8.146
100	8.136	40	8.146
90	8.137	30	8.145
80	8.137	20	8.143
70	8.144	10	8.144
60	8.146		

PLATE I.

RIFLING.

uniform; one turn in 30 feet
oves and Lands each { Width of Lands 0.349
s 0.065 inch deep { Width of Grooves 0.6982
es filleted with a rad. of 0.075
beveled with a rad. of 0.01
g to begin 15.5 inches from bottom of bore
the left of axis of bore.



Appendix 26—1884.

APPENDIX 27.

PROGRESS REPORT UPON THE MANUFACTURE OF FIFTY 8-INCH COILED WROUGHT-IRON TUBES, BREECH INSERTION, FOR CONVERSION OF 10-INCH RODMAN SMOOTH-BORE GUNS INTO 8-INCH MUZZLE-LOADING RIFLES, AT THE WEST POINT FOUNDRY, UNDER CONTRACT DATED JUNE 12, 1883.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(6 plates.)

The service numbers of these fifty coiled wrought-iron tubes made on the breech-insertion plan extend from No. 30 to No. 79, inclusive. They were made and rough finished at this foundry, and shipped to the South Boston Iron Works to be inserted in the cast-iron casings.

The work was commenced June 6, 1883, with the solid forgings for the breech end of the jackets. The first lot of bar-iron for the coils was received June 20, 1883, and the first lot of five tubes was completed October 17, following, and shipped to South Boston. The delivery of the bar-iron was completed December 6, 1883, and the final shipment of tubes made to South Boston April 8, 1884. This would have completed the contract except for the necessity of replacing two tubes rejected for defects developed under the firing proof following their insertion in the cast-iron casing. One of these tubes has been finished, but at this date (August, 1884) the iron for the remaining one has not been received.

During the manufacture of the fifty tubes made between June 6, 1883, and April 8, 1884, a period of ten months, the capacity of the works was fairly tested, and gives an outcome of five tubes per month. This time includes the usual delays incident to the delivery of the bar-iron and to the recommencement of this work at the foundry after several years cessation. After getting fairly started and under timely deliveries of the iron the tubes were turned out at the rate of about ten per month.

The manufacture of these tubes has been fully described in late annual reports of the Chief of Ordnance.* Six plates have been prepared to accompany this report, for illustration of the work, as follows:

PLATE I.—Bars prepared for butt-welding and coiling.

PLATE II.—Mandrels and sleeves used in coiling the bars, Figs. 1, 2, 3, and 4; the dies used in forging the breech cups, Fig. 5; and an illustration of the way in which the forged slab is shaped for welding the muzzle collar, Fig. 6. Fig. 3 shows the mandrel (or sleeve) at first used for coiling the heavy jacket sections. It was soon found, however, that the coil compressed the sleeve so much as to make it difficult to

withdraw; the solid shaft, Fig. 4, with the usual taper, was then substituted for the sleeve.

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* Annual Report of the Chief of Ordnance, U. S. Army, for the year 1877, pp. 400 to 412; for the year 1878, pp. 351 to 356, and for the year 1880, pp. 104 to 126.

PLATE III.—The welding pots and "cheese" used for coil welding the sections.

PLATE IV.—Details of the coils, the welded sections, and the sections prepared for the tube (or press) welding of the inner tube and jacket.

PLATE V.—The details of tube welding and showing the average length of the sections before and after the end welding with the positions of the joints.

PLATE VI.—The completed tube and muzzle collar as finished for delivery.

The bar-iron used in the tubes was manufactured by Tuckerman, Mulligan & Co., at the Ulster Iron Works, Saugerties, N. Y. Before acceptance two specimens taken from each quality of iron in each lot received were subjected to mechanical tests. The following gives a summary of the weights, dimensions, and mechanical properties of the bar-iron supplied to date under the contract in lots as received:

Statement of weights, dimensions, and mechanical properties of Ulster bar-iron supplied by jacketed coiled wrought-iron tubes and muzzl

Date of receipt.	Quality and use.	Number of pieces.	Dimensions.			Weights.		Date of acceptance.	Where tested.	Mechanical properties.	
			Size.	Length.		Average per piece.	Total.			Specimen (round bar).	
										Taken from—	Mark.
1883.				Ft.	In.	Pds.	Pds.	1883.			
June 20	A-iron for inner tubes, in bars.	29	2¼ sq.	26	6	454. 0	13, 165	July 11	U.S.P.G., Sandy Hook, N.J.	Test pieces.	A A
July 3		138	2¼ sq.	26	6	455. 74	62, 802	July 14	......do............	....do ...	A 1 A 1
Sept. 27		50	2¼ sq.	26	6	458. 0	22, 900	Oct. 10	......do............	Bars	A 2 A 2
Oct. 11		70	2¼ sq.	26	6	458. 5	32, 092	Oct. 25	......do............	....do ...	A 3 A 3
Nov. 2		25	2¼ sq.	26	6	463. 6	11, 589	Nov. 5	W. P. F............	....do ...	A 3 A 3
Nov. 29		18	2¼ sq.	26	6	449. 0	8, 082	Dec. 12	U. S. P. G., Sandy Hook, N. J.	....do ...	A 5 A 5
Dec. 6		88	2¼ sq.	26	6	454. 6	40, 011	Dec. 18	......do............	....do ...	A 6 A 6
1884. May 12		8	2¼ sq.	26	6	457. 5	3, 660	1884. May 27	......do............	....do ...	A 7 A 7
		426	....	....		456. 4	194, 391				
1883. June 20	B-iron for jackets, in bars.	50	2¼ sq.	27	1	463. 1	23, 156	1883. July 11	......do............	Test pieces.	B B
Nov. 29		42	2¼ sq.	27	1	463. 2	19, 455	Dec. 12 Dec. 14	......do............	Bars	B 3 B 3
		92	....	....		463. 15	42, 611				
June 20	Bar iron, for jackets, in bars.	46	4x3¼x3¾	19	1	773. 1	35, 563	July 11	......do............	Test pieces.	B 1 B 1
July 3		30	4x3¼x3¾	19	1	774. 7	23, 242	....	W. P. F...........	Bars	B 2 B 2
								July 25	U. S. P. G., Sandy Hook, N. J.	....do ...	B 2 B 2

Messrs. Paulding, Kemble & Co., at the West Point Foundry, under contract for fifty 8-*inch -collars, breech insertion, dated June* 12, 1883.

Mechanical properties.											
Original.			Elastic limit.		Ultimate.			Ratio of elastic to ultimate resistance.	Contraction in area at fracture.	Fracture.	
					Resistance.						
Length between shoulders.	Diameter.	Area of cross-section.	Resistance per square inch.	Extension per inch of length.	Original area per square inch.	Fractured area per square inch.	Extension per inch.			Position.	Character.
In.	*In.*	*Sq. in.*	*Pds.*	*In.*	*Pds.*	*Pds.*	*In.*		*P. ct.*		
3.00	0.576	0.260572	4,0000	.001	49,000	93,940	0.295	2.04	47.84	Middle	Close fibrous.
3.00	0.5755	0.260122	7,0000	.00133	49,000	97,955	0.31	1.815	49.98	....do	Do.
3.00	0.57	0.25517	30,000	0.001	50,000	97,598	0.289	1.66	48.76	One-third from shoulder.	Do.
3.00	0.571	0.25607	26,000	0.00166	49,000	95,975	0.315	1.88	48.90	Near middle	Do.
3.00	0.57	0.255176	27,000	0.001	48,000	90,100	0.2983	1.78	45.50	One-third from shoulder.	Fine uniform fibrous.
3.00	0.57	0.255176	27,000	0.001	50,000	103,600	0.326	1.85	51.73	....do	Do.
3.00	0.57	0.255176	22,000	0.00166	50,000	88,690	0.20	2.27	43.62	Near middle	Fibrous.
3.00	0.57	0.255176	23,000	0.001	51,000	94,842	0.241	2.2	46.22	Near shoulder	Fibrous, with minute scattered crystals.
2.25	0.57	......	......	......	50,945	......	0.342	......	......	Middle	Uniform, fine fibrous small crystals.
2.25	0.5685	......	......	......	49,240	......	0.32	......	......	Near middle	Fibrous and crystalline, with seams in specimen.
3.00	0.57	0.2552	24,000	0.00066	50,000	95,250	0.284	2.08	47.50	One-third from shoulder.	Fibrous.
3.00	0.569	0.25428	27,000	0.00133	50,000	98,700	0.284	1.85	49.33	....do	Do.
3.00	0.567	0.252497	27,000	0.001	50,000	98,977	0.3136	1.85	49.50	Near middle	Do.
3.00	0.5655	0.25116	25,000	0.001	51,000	92,910	0.2853	2.04	45.10	....do	Do.
3.00	0.571	0.25607	23,000	0.00133	49,000	88,876	0.223	2.13	44.86	One-fourth from shoulder.	Uniform fibrous.
3.00	0.571	0.25607	23,000	0.001	52,000	91,700	0.258	2.26	43.30	....do	Do.
...	......	......	25,357	0.00115	49,887	94,936	0.2921	1.979	47.44		
3.00	0.5755	0.260124	25,000	0.00066	49,000	100,900	0.309	1.96	51.45	Middle	Close fibrous, with scant very minute crystals.
3.00	0.5745	0.25922	27,000	0.00066	48,000	98,020	0.32	1.78	51.00	Near middle	Do.
3.00	0.57	0.2552	23,000	0.00066	49,000	97,070	0.283	2.13	49.50	Middle	Fibrous.
3.00	0.571	0.25607	29,000	0.00166	50,000	101,600	0.328	1.73	50.80	....do	Fibrous and few crystals.
...	......	......	26,000	0.00091	49,000	99,397	0.310	1.90	50.69		
3.00	0.576	0.260576	25,000	0.001	50,000	76,725	0.248	2.0	34.83	Near middle	Fibrous, with crystalline spots.
3.00	0.576	0.260576	25,000	0.00066	49,000	85,525	0.292	1.96	42.70	....do	Fibrous and fairly close.
2.25	0.569	......	......	......	49,750	......	0.337	......	46.55	....do	Fibrous, with few minute crystals.
2.25	0.57	......	......	......	50,740	......	0.342	......	44.90	....do	Do.
3.00	0.569	0.25428	23,000	0.001	49,000	93,460	0.290	2.12	47.57	...do	Fibrous.
3.00	0.569	0.25428	18,000	0.00166	48,000	95,690	00.322	2.06	49.84	....do	Do.

Statement of weights, dimensions, and mechanical properties of Ulster bar-iron sup

Date of receipt.	Quality and use.	Number of pieces.	Dimensions.		Weights.		Date of acceptance.	Where tested.	Mechanical properties.	
									Specimen (round bar).	
			Size.	Length.	Average per piece.	Total.			Taken from—	Mark.
1883.				*Ft. In.*	*Pds.*	*Pds.*	1883.			
	B-iron, for jackets, in bars.							W. P. F	Bars....	B 2 B 2
Dec. 6		26	4x3¼x3¼	19 1	768.3	19,976	Dec. 18	U. S. P. G., Sandy Hook, N. J.	....do ...	B 4 B 4
		102	....	......	772.3	78,781				

Remarks.—Subsequent to lots received July 3d, all specimens for test were taken from the bars
The tests at Sandy Hook were made upon the Rodman testing machine in charge of Lieut. C. W.
measuring progressive extensions, &c.

Note.—The standard physical properties established for the acceptance of the bar iron are: Ulti
fracture equal to 0.3 inch.

plied by Messrs. Paulding, Kemble & Co., at the West Point Foundry, &c.—Continued.

Mechanical properties.											
Original.			Elastic limit.		Ultimate.					Fracture.	
					Resistance.						
Length between shoulders.	Diameter.	Area of cross-section.	Resistance per square inch.	Extension per inch of length.	Original area per square inch.	Fractured area per square inch.	Extension per inch.	Ratio of elastic to ultimate resistance.	Contraction in area at fracture.	Position.	Character.
In.	*In.*	*Sq. in.*	*Pds.*	*In.*	*Pds.*	*Pds.*	*In.*		*P. ct.*		
2. 25	0. 57	0. 25517	......	....	49, 965	72, 560	0. 298	....	31. 14	One-third from shoulder.	Close fibrous, with few crystals.
2. 25	0. 57	0. 25517	......	....	49, 965	88, 000	0. 306	...	43. 22	...do	Close fibrous, with minute crystals.
3. 00	0. 57	0. 2552	21, 000	0. 001	49, 000	92, 448	0. 287	2. 33	47. 00	Three-fourths from shoulder.	Fibrous.
3. 00	0. 57	0. 2552	23, 000	0. 001	49, 000	87, 735	0. 307	2. 13	44. 15	Near middle	Fibrous fine crystals.
....	.....	....	22, 500	0. 00105	49, 442	86, 518	0. 302	2. 20	43. 19		

themselves, for which purpose two bars of each quality were rolled with extra length.
Whipple; those at the West Point Foundry upon the machine used there, which has no appliances for

mate strength 50,000, and elastic limit 25,000 pounds per square inch, with an extension per inch at

A report upon the manufacture and tests of the solid forgings for the breech ends of the jackets is given in the Annual Report of the Chief of Ordnance, U. S. Army, for 1883, page 215.

The tubes were made and put together in the usual manner. They were subjected to a preliminary water test of 120 pounds pressure in their rough state immediately following the press welding.

Some observations made upon the shrinkage of the highly-heated sections, after they were removed from the welding pots, gave the following results: A diameter of 16.25 inches shrunk 0.375 inch; one of 14.375 inches shrunk 0.3125 inch, and one of 12.25 inches shrunk 0.25 inch on cooling down from a welding heat, giving the following rates of shrinkage per inch of diameter: 0.02255, 0.021276, and 0.0198. The special importance of this bears upon the size of bore of welding pots, so as to leave sufficient metal to turn off the rough piece when cold.

In shrinking the heated jacket upon the tube the bore of the jacket was at first made about 0.125 shorter than the corresponding portion of tube; it was afterwards found that this shortage could be lessened to 0.1 inch without danger to a firm seat of the tube at the bottom of the bore of jacket, that is, it was determined that the longitudinal expansion of the bore of jacket, lenghth 43 inches, was when heated about 0.1 inch. When the jacket was cooled it shrunk away from the shoulder on tube to the extent, on an average, of about 0.05 inch, leaving that space to be calked in the usual manner, and the length of bore of jacket permanently extended 0.05 inch. The shrinkage under jacket being 0.003 inch, it was heated in a wood fire sufficiently to allow the free entrance of a gauge 10.52 inches in diameter, thus providing for an expansion of at least 0.02 inch over the portion of the tube to be encompassed.

Two changes were made in the prescribed dimensions during the course of manufacture, one with reference to the space mentioned above; to enable the calking to be made as effective as possible, the diameter of "first reinforce of tube" was reduced from 11.6 to 11.55 inches, leaving 0.05 inch to be removed in finishing the tube for insertion in the cast-iron casing. The second change was made to leave the diameter of neck of tube 9.9 inches unfinished, thus leaving the whole exterior of the tube to be finished turned in a single lathe at South Boston.

In the inspection of the work during the regular course of manufacture the first defect developed by the method of construction in vogue was at the "scarfing" stage. To make the V for the scarf joint the end of the bar is split along a plane of the "pile" incident to the manufacture of the bars at the rolling mill. The result is that sometimes the split extends into the bar beyond the point of the V, and creates a receptacle for scales and cinder within the iron during the welding of the joint.

In coiling the bars the curvature coincides with the flat of the V, and it sometimes happens that the joint is torn at the point on the outside, leaving a cavity in the bar. When this occurs it is remedied by cutting the cavity out and inserting a piece of tube iron to completely fill it. The part should then become perfectly sound in the subsequent coil-welding operations.

In finishing the tube, especially as regards the bore, defects in welding and cinder marks or small cavities may be expected to develop as the boring progresses; all such defects are, however, believed to be entirely due to the manufacture of the tube itself, to be situated at the joints of the coils, and to arise from imperfect coil welding, or from cinder or scale caught during the operations. The Ulster bar-iron itself is remarkably free from dangerous seams. In the case of one tube, the rough boring to 7.93 inches showed a good surface, but when it was finished, bored to 8 inches, two cavities were uncovered at coil joints within about 16 inches of the muzzle which caused the rejection of the tube. This, however, was but one out of fifty tubes. In others slight seams were not unfrequently developed, but insufficient in themselves to be considered of dangerous import. None of the tubes made gave any evidence of leakage under the water test. On the exterior of the tube the only defect to be remarked was an occasional slight roughness in the first reinforce arising from pit holes caused by the fire in the coil-welding operations. This portion of the tube, a length of about 8 inches when finished, has a relatively greater diameter with reference to the rough-forged diameters than any other, and consequently less metal is removed from the outside in finishing. Such defects as arose in this way were, however, plainly seen to be superficial and not serious.

With the present method of inserting the wrought-iron cup in bottom of tube, a difficulty arises about securing a perfectly smooth contour at the junction of the curve of its lip with the adjoining fillet in tube. The cup is entirely finished before insertion; it is threaded over its whole exterior, and where the thread runs out at the lip end a portion of the lip is left so thin that it spreads in cutting the thread in the lathe, and although this is corrected before the insertion, the same thing is liable to occur when the cup is screwed in; moreover, where this thread runs out, a portion of the edge of the cup is cut away. The after "finish" boring and reaming of the fillet in the tube cannot more than partially correct the roughness at the extremity of the thread, for the operation of the cutting tool does not extend within the cup. A remedy for this would appear to lie in stopping the thread on the exterior of the cup short of the thin edge of the cup.*

The following are the principal dimensions of the tube as made at this foundry preparatory to shipment for final finish and insertion at the South Boston Iron Works (see Plate VI):

Subject of measurement.		Dimensions.	Remarks.
		Inches.	
Total length of tube		147.66	Three inches surplus left at muzzle.
Total length of inner tube and jacket		140.41	
Projection of breech-plug in rear of tube		7.25	
Length of bore of tube		120.25	
Length of neck of tube		8.0	
Length of chase of tube		71.27	
Length of first reinforce of tube		8.73	
Length of second reinforce of tube		36.91	
Length of third reinforce of tube		7.0	
Length of fourth reinforce of tube		16.5	Left for threads.
Diameter of bore of tube		8.0	Not rifled.
Diameter of neck of tube		9.9	Rough-turned to dimensions varying from 0.1 to 0.3 inch over finished sizes.
Diameter of chase of tube		10.8	
Diameter of first reinforce of tube		11.55	
Diameter of second reinforce of tube		13.6	
Diameter of third reinforce of tube		14.8	
Diameter of fourth reinforce of tube		15.6	
Length of muzzle collar		7.0	
Diameter of muzzle collar	interior	9.76	
	exterior	11.85	Rough-turned.
Incisions in muzzle collar	depth	0.875	
	width	2.0	
Total length of jacket		60.41	

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* It is believed, however, that the tubes previously constructed, as these present have been, have performed well in service.

Subject of measurement.	Dimensions.	Remarks.
	Inches.	
Length of jacket in rear over inner tube	17.41	Hydraulic tests of tube: Pressure of 120 pounds applied to inner tube and jacket in forged and welded state; also to jacket with finished bore and to tube with bore of 7.93 inches, *i. e.*, when prepared for assemblage.
Length of jacket over inner tube	43.0	
Interior diameter of jacket over inner tube	10.5	
Exterior diameter of tube under jacket	10.503	
Corresponding shrinkage	0.003	
Total length of inner tube	123.0	
Radius of curve at bottom of bore of jacket	1.20	
Radius of curve at bottom of tube	1.25	
Length of dowels (2) for securing tube to jacket	2.0	
Diameter of dowels for securing tube to jacket	0.75	
Thickness of wrought-iron cup at bottom of tube	2.75	
Total length of cup	5.5	
Diameters at interior of cup { top	7.0	
Diameters at interior of cup { bottom	4.6	
Diameter of cup over threads	7.8	
Pitch of thread on cup	3 to the inch.	
Total length of cast-iron breech plug	24.66	
Length of breech plug within jacket	17.41	
Length of thread on breech plug	16.41	
Diameter of breech plug over threads	7.0	
Pitch of thread on breech plug	0.25	
Diameter of shoulder on breech plug	9.75	
Thickness of shoulder, including curved portion	1.25	
Length of square at base of plug	6.0	
Side of square at base of plug	5.0	
Length of securing pin through shoulder on plug	4.25	Low steel.
Diameter of securing pin through shoulder on plug	1.0	
Weight of tube ....pounds	3,130	
Weight of muzzle collar ....pounds	68	
Total weight ....pounds	3,198	

The work is under inspection at all stages, and the tube may be rejected upon the detection of defects in material, plans, imperfect welds or cinder marks, especially in the bore, or poor workmanship. The tube is not finally accepted until the finished gun has passed the powder proof prescribed with service charges.

MATERIAL AND LABOR.

The completed tube comprises the following parts (see Plate VI):

1. The inner tube made entirely of rolled iron bars, quality A.
2. The breech-cup which closes the bottom of the inner tube, forged solid from ends of the A iron bars cut off at the rolling-mill in squaring the ends of the bars.
3. The jacket made of rolled iron bars, quality B, except a section at the breech (11.16 inches outside length) forged solid from mixed Ulster tube iron scrap.
4. The two dowel pins of wrought iron fixed in the base of the tube and let into the jacket to assist in securing the two parts together.
5. The cast-iron breech plug of gun metal.
6. The securing pin through shoulder of breech plug, made of low steel.
7. The muzzle collar forged and welded from wrought iron scrap of fine quality.

The material required for the several parts of a single tube is as follows:

Material required for one 8-inch coiled wrought-iron tube, breech insertion.

Parts of tube.	Quality of iron.	Number of bars.	Dimensions.			Average weight per piece.	Total weight.
			Length.		Cross-section.		
			Feet.	*Inch.*	*Inches.*	*Pounds.*	*Pounds.*
Inner tube	A iron in bars	8	26	6	2.25 square.	456	3,648
Breech-cup	A iron scrap	bar ends					137
Jacket	B iron in bars	2	27	1	2.25 square.	463.5	927
		2	19	1	4 × 3¼ × 3⅜ hexagonal.	777	1,554
	Ulster tube iron scrap						1,164
Breech plug	Cast (gun metal)						402
Muzzle collar	Wrought scrap of fine quality.						142

NOTE.—The A and B iron refer to Ulster tube iron. In the case of the solid forgings the total weight given includes an increase of 20 per cent. over the weight of the rough forged pieces, to allow for loss of weight in forging to size. The two dowels and securing pin (low steel), which are of small dimensions, are omitted.

Fuel.—The several operations in the smith shop require the use of a heating furnace for "coiling" the bars; a large reverberatory furnace for forging the solid breech-pieces and the "coil welding"; a smaller reverberatory furnace for forging the breech cups and muzzle collars; a press furnace for "tube welding," and forge fires for scarping and "butt welding" the bars, shaping the coils, shrinking together the sections, and welding the muzzle collars; the fuel used in the furnaces must be of good quality. The use of an impure coal has been found to ruin the welding qualities of the iron, which, especially the A iron, has so much of the cinder removed in the rolling process that it is denominated "dry." The fuel commonly used at this foundry is Cumberland (soft) coal. Pennsylvania gas coal was used during a part of the time; it possesses the doubtful advantage of giving a fiercer fire and more heat than the Cumberland coal. An approximate estimate of the amount of coal consumed in forging each tube gives, for the furnaces, 20,000 pounds, or 8.9 tons, and for the forge fires 900 pounds.

A suitable crane is provided for each furnace, and the following steam hammers are in use: For the coil welding and heavy forgings one of 8 tons, single acting; for forging the muzzle collars and breech cups, one of 3,000 pounds, double acting; in connection with the tube welding, one of 3,300 pounds, single acting; and in connection with the butt welding of the heavy bars an unnecessarily heavy hammer of 5,000 pounds, single acting.

Labor.—The work in the smith shop requires 1 foreman, 4 blacksmiths, 2 machinists, 3 stokers, and about 13 helpers. The labor expended per tube is, approximately: Foreman, 5 days; blacksmith, 7.5 days; machinist, 7 days; stoker, 5 days; and helper, 90 days, of 10 hours each. In the finishing shop about 10 lathes and 6 boring beds find nearly constant employment when the work is well in hand. The labor expended per tube is, approximately: Foreman, 5 days; machinist, 46 days; machinist (fitter), 2 days; and helper, 20 days. The lathes and bouring beds vary in capacity from 24 to 42 inches swing. In the outside department, the handling of the iron, &c., will employ: Foreman, one-half day; helper, 2 days.

PLATE I.

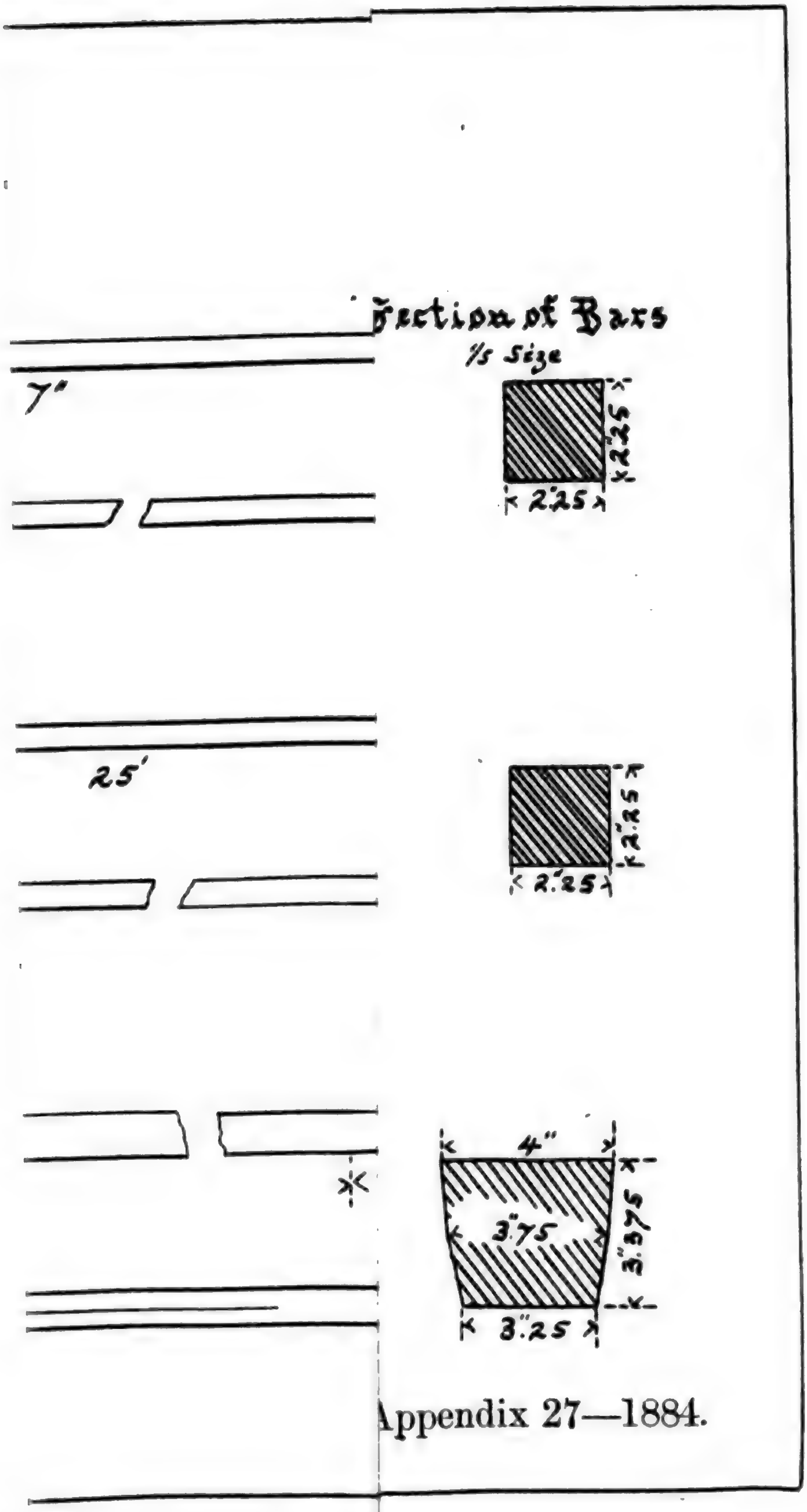

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PLATE II.

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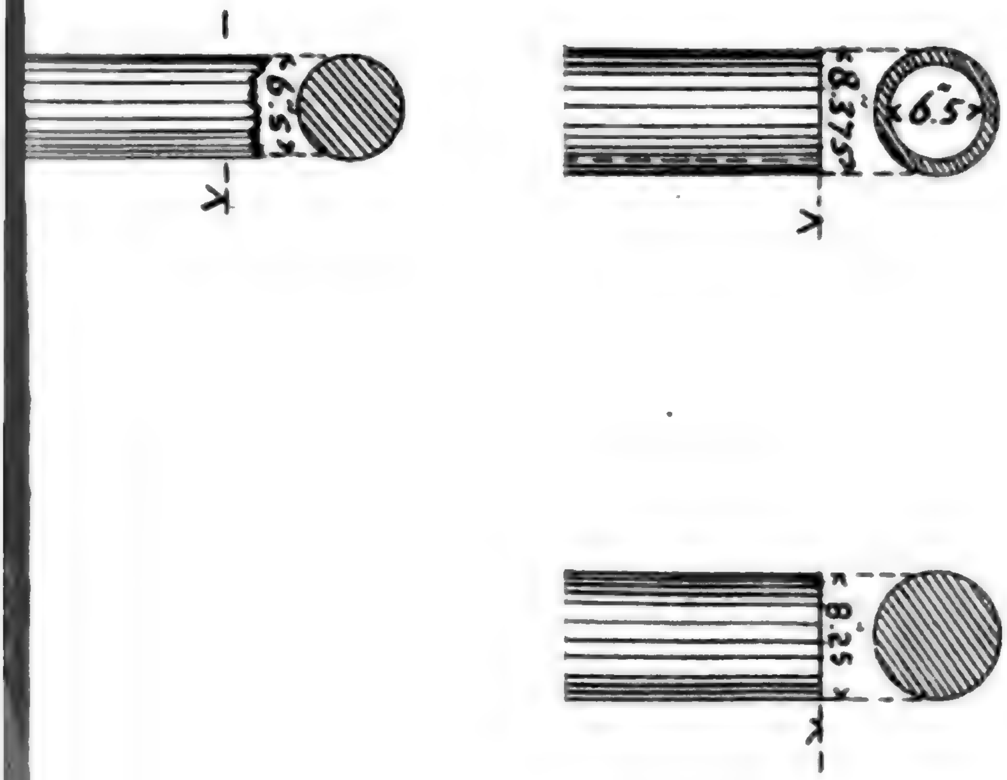

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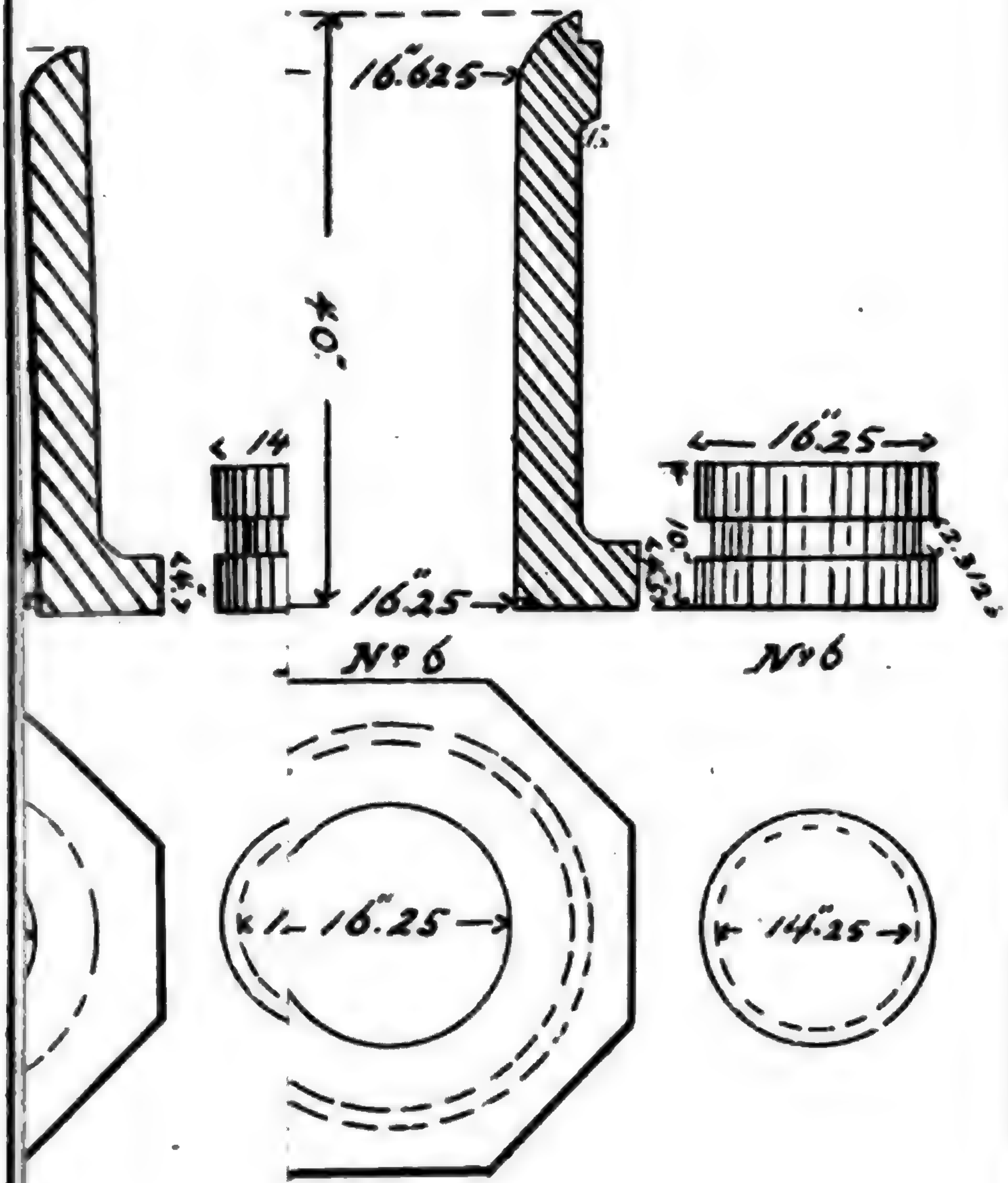

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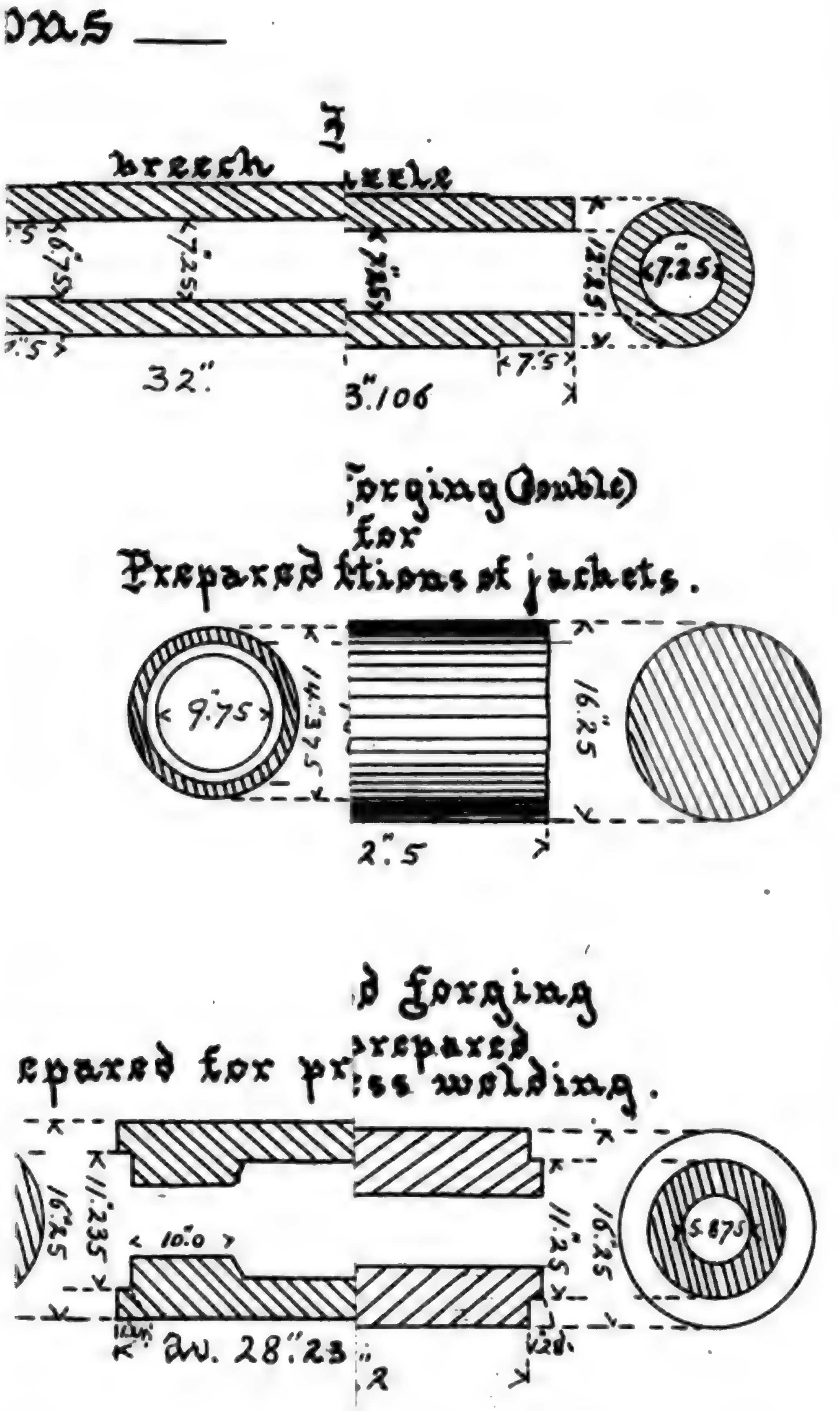
Appendix 27—1884.



Appendix 27—1884.

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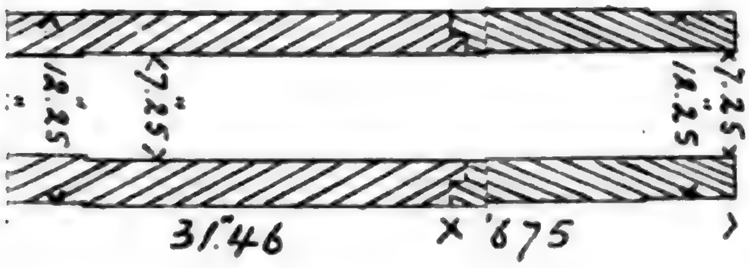

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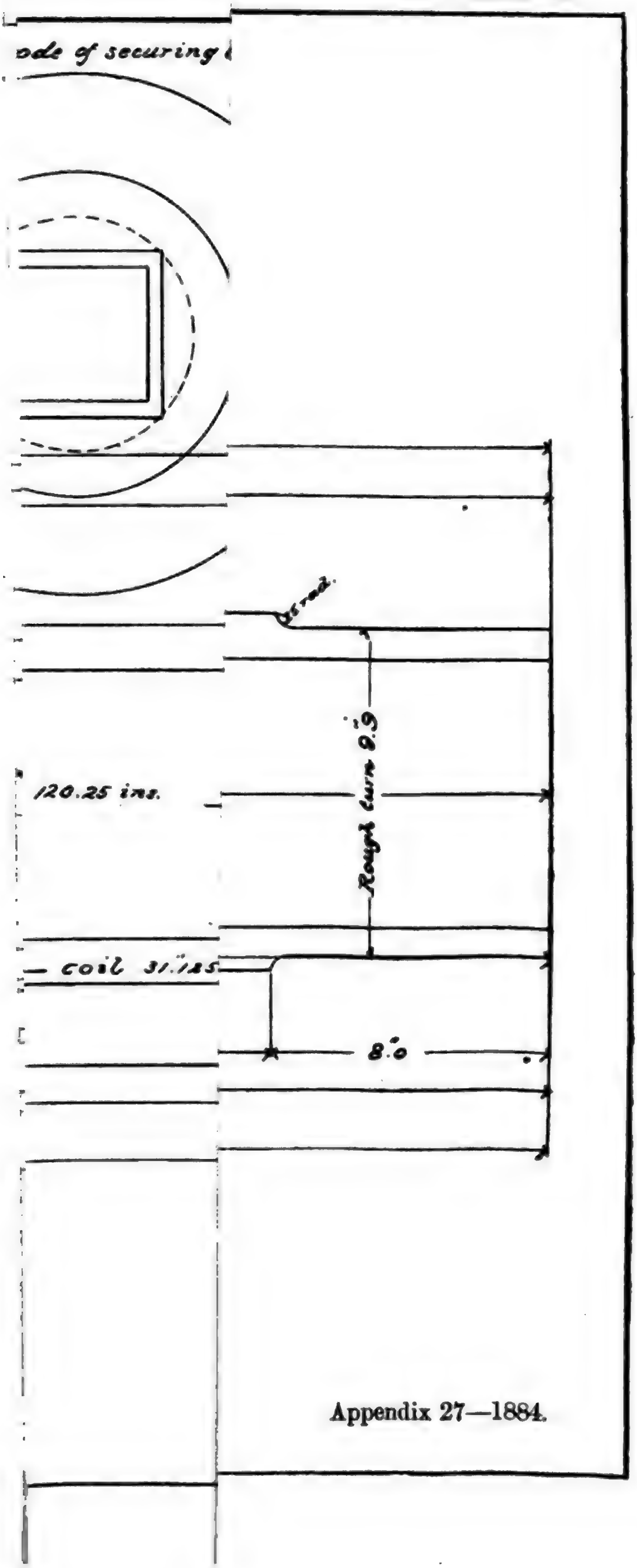
PLATE VI.



Appendix 27—1884.

APPENDIX 27*a*.

OFFICE OF INSPECTOR OF ORDNANCE, U. S. ARMY,
WEST POINT FOUNDRY,
Cold Spring, N. Y., October 16, 1883.

The CHIEF OF ORDNANCE, U. S. ARMY,
Washington. D. C.:

GENERAL: I have the honor to submit the following report in regard to one of the 8-inch coiled wrought iron tubes now being made at this foundry under contract dated June 12, 1883, and to request authority to have the same *rifled* at this foundry and inspected in that state before it is sent to the South Boston Iron Works for insertion. This request is based upon the fact that there exists in bore of the tube, at a point 35 inches from the base, a slight defect, which, by using care in the rifling, can, I believe, be entirely removed, that is by the cutting of the grooves. I am well informed about the nature of this defect and its cause, and have not up to this time rejected the tube for the reasons herewith given.

My attention was first called to a defect in this tube (the inner tube only) on September 10, when the tube was rough turned the second time, to an outside diameter of 11.25 inches over the portion at the breech which comes within the jacket, this being about 0.25 inch on a side above the finished exterior. There was developed on the outside a defect at the *point* of the scarf-joint where the two bars forming the rear section of the tube had been joined end to end in butt-welding. This defect was about 0.1 inch in diameter, and deep enough to allow the insertion of a pin to a depth of 0.6 inch, that is to say if the tube had been finished in this state, this defect would have extended about half way through the wall of the inner tube from the outside. The distance of this defect from the breech of the tube was 16 inches.

As the tube could not be accepted in this state, the contractors undertook a remedy which thus far promises success.

When the exterior defect was discovered the bore of the tube was enlarged to about 7.94 inches or $\frac{1}{16}$ inch less than the finished bore, and this constituted the principal difficulty, for it left practically no margin for the bending of the tube, which would probably occur in reheating it.

To remedy the defect an attempt was first made to weld a piece into the tube from the outside in an ordinary forge; to do this a wedge-shaped opening was cut in the tube deep enough to take out all the defective part. A corresponding wedge of tube iron was also made to fit this opening. The tube and piece were then heated separately to a welding heat and the piece welded in by hammering. To prevent injuring the bore during this operation, a mandrel of tube iron 27 inches long, 0.625 inches less than the bore at its larger end, and having a taper of 0.125 inches, was inserted in the bore from the muzzle and rested under the portion of the tube operated upon. This attempt, although successful in so far as the welding of the piece was concerned, left the tube in apparently worse condition than before, since the open fire had wasted away as much of the iron at the place of welding that insufficient metal was left to finish the exterior of the tube.

The tube having a surplus of length was then put into the press-welding furnace, where it was evenly heated throughout the portion adjacent to the defective part and "upset" until the exterior diameter was restored to sufficient dimensions to finish. In this operation, also, the mandrel was placed in the bore within the part heated in order to keep it straight. After the upsetting in the press furnace and subsequent "tapping" under the hammer to make the exterior cylindrical and straight, the tube was left to cool. It was then found that the mandrel could not be extracted. This rendered it necessary to slightly reheat the tube, when the mandrel was driven out with great difficulty from the rear (the breech cup was not yet inserted). After the mandrel was extracted it appeared that its surface had been imperfectly welded in spots to the interior of the tube, and that in forcing it out the bore of the tube had been badly abraded at these spots, appearing like the surface of a stick of wood in which a series of cuts had been made with a knife without detaching the shavings. It was found, owing to these abrasions, that the bore would not finish to 8 inches at the part operated upon. The tube was therefore once more placed in the press-furnace, reheated and finally "tapped" on the outside under the hammer to reduce the bore.

The tube was then taken back to the finishing shop and again bored out to a diameter of 7.94 inches. This entirely removed the abrasion of the bore, except in two spots situated near together in the direction of the axis of the tube, at a distance of 35 inches from the base. An impression of the bore was then taken, which showed these defects to be of so slight depth as to warrant the belief that they would be removed by finishing the bore to 8 inches. This has been done, and the only defects now remaining are a scarcely perceptible roughness at one place and an abrasion about 0.02 inch deep at the other. These two defects are so slight and are so situated that there is good reason to believe they can be removed by rifling the tube so that one of the grooves will intersect and remove them both, the groove being 0.6982 inch wide and 0.075 inch deep.

The exterior of the tube has also been rough-turned and found to be of sufficient dimensions to finish to the diameter required, *i. e.*, 10.5 inches.

The Messrs. Paulding, Kemble & Co. ask to be allowed to rifle the tube themselves, and without expense to the Government, in which request I concur, not only because I think an imperfect tube should not be passed by the inspector at this foundry, but also because the workmen here are, from their knowledge of this tube, best situated to make it finally satisfactory to the Government, if that can be done.

There might have been apprehended from this treatment a degradation of the iron, due to overheating. Except when the outside wasting occurred in the open fire, however, the several heatings were made very slowly and carefully, and, it is believed, without injury to the iron. In the open fire the heat was applied only to one place on the outside of the tube, and this place now shows clean and perfect.

The operations yet to be performed before the tube can be rifled are:

1. Insertion of the breech cup.
2. Turning down the breech in preparation for shrinking on the jacket.
3. The shrinkage.

4. Reboring the tube to its finished diameter of 8 inches, in order to remove any compression of the present bore which may be induced by the shrinkage.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

[First indorsement.]

ORDNANCE OFFICE,
Washington, October 18, 1883.

Respectfully returned to Lieut. R. Birnie, jr., Cold Spring, N. Y., approving his recommendation that the tube within referred to be rifled at the West Point Foundry, and at the expense of the West Point Foundry Association; provided that by so doing no injury will come to the rifling in the subsequent operations of finishing and inserting it within its cast-iron casing.

By order of the Chief of Ordnance.

CHAS. S. SMITH,
Captain of Ordnance, Principal Assistant.

[Second indorsement.]

WEST POINT FOUNDRY,
Cold Spring, N. Y., November 21, 1883.

Respectfully returned to the Chief of Ordnance, U. S. Army. It having been definitely decided that the rifling of this tube would not be injured by subsequent operations, the tube was finished in a uniform way and finally rifled. It was closely inspected to-day and accepted as satisfactory in all respects.

R. BIRNIE, JR.,
Lieutenant of Ordnance.

APPENDIX 27*b*.

REPORT UPON THE CONSTRUCTION OF CONVERTED 8-INCH RIFLE NO. 39, BREECH INSERTION, AND EXAMINATION OF DEFECT IN 8-INCH COILED WROUGHT-IRON TUBE NO. 39 (ORIGINAL), AT THE WEST POINT FOUNDRY.

(1 plate.)

WEST POINT FOUNDRY,
Cold Spring, N. Y., August 6, 1884.

The CHIEF OF ORDNANCE, U. S. ARMY,
Washington, D. C.:

GENERAL: Upon the completion of converted 8-inch rifle No. 39 (breech insertion) at this foundry, I have the honor to submit the following report:

The original gun of this number was declared unsatisfactory when examined subsequent to its firing proof, as appears from the following:

[Fourth indorsement.]

UNITED STATES ORDNANCE PROVING GROUND,
Sandy Hook, N. J., April 1, 1884.

Respectfully returned to Col. T. G. Baylor, commanding (through Capt. W. P. Starring), with the information that the guns within referred to have been subjected to the proof as directed. The proof of gun No. 39 was not satisfactory, and I return the inspection report for that gun unsigned. A depression 1.5 inches wide and 0.25 to 0.3 inch deep was developed in the bore of the gun at a distance of 88 inches from the muzzle. It extends in a general direction at right angles to the axis so as to cover about five grooves. It is gradual, and there is apparently no break in the continuity of the surface.

C. W. WHIPPLE.
Lieutenant of Ordnance.

Subsequently, at the request of Paulding, Kemble & Co., and by your authorization, dated April 19, 1884, the gun was shipped to this foundry, where it has been reconstructed.

First after its receipt the gun was entirely dismantled.

1. The copper vent piece was unscrewed without difficulty and was preserved uninjured.

2. The securing pin between casing and tube was removed by drilling a hole within it, which hole was afterwards squared and served as a receptacle for a wrench.

3. The muzzle collar was started by means of a cold chisel held against the outer face and a sledge struck against the head of the chisel. After being started the collar was unscrewed by hand.

4. The entire tube was unscrewed from the casing. To accomplish this the gun was mounted upon a lathe-bed and arranged to revolve slowly, soft metal supports being arranged, one under chase near the muzzle, the other at the neck of the breech. An inclosure of brick was

then built about the gun and covered to enable it to be thoroughly heated; the portion of the gun exposed to the heat extending along the middle portion to within about 20 inches of the breech and muzzle ends. A strong gearing of cog-wheels was firmly connected with the breech of the tube by which the motive power of the shop was used for the unscrewing. A current of cold water was arranged to circulate through the bore of the tube. On May 3, 1884, a wood fire was lighted under the gun at 8.30 a. m.; cold water was supplied within the bore and the gun was kept slowly revolving. The fire was drawn about 3 p. m., when the gun was considered sufficiently hot, its temperature being probably between 500° and 600° Fahr., as judged from the action of water when thrown upon it. The gun was then clamped in its bed and the tube started by applying hydraulic jacks to act upon the spokes of the cog-wheels directly connected with the breech of the tube. After the screw was started the machinery was set in motion and the unscrewing completed. The gun was then swung out of the lathe and the remainder of the tube withdrawn directly with an ox team and block and tackle. The current of water was maintained in the bore until the last stage of the operation. The above was effected without special difficulty, but the arrangements were very complete and involved a good deal of time and labor.

5. The securing pin through shoulder of cast-iron breech plug was drilled out and the plug unscrewed.

6. The jacket was separated from the inner tube as follows: The tube (entire) was mounted in the foundry yard upon two supports, one at breech, the other near muzzle, so that the axis was horizontal and about 30 inches above the ground. A heavy cast-iron collar or cross-head was passed over the chase of tube to abut against the forward end of jacket; another cross-head was placed on the same level about 30 inches in rear of the breech, and these two cross-heads were connected by two heavy iron rods, outside of and parallel to the jacket, and having a thread and nut on each at the rear cross-head. The threaded opening in breech of tube from which the breech plug had been taken was lined with sheet copper to protect the threads and an iron cylinder passed in to abut against the base of the inner tube and project a few inches from breech of jacket. Between the rear end of this and the rear cross-head an hydraulic jack was placed, so that upon applying the power the tube would be moved forward and out of the jacket. An open brick structure was built to apply fire (wood) under the jacket and a current of cold water was arranged to circulate through the bore of tube. During the heating the tube was slowly revolved. When the fire was drawn the side rods were passed through the cross-heads, and by adding piece by piece to the cylinder between base of tube and the hydraulic jack the inner tube was slowly pushed out.

The operation was performed with great difficulty, owing to the fact that it was scarcely possible to expand the jacket and contract the tube at the same time, but by rebuilding the fire several times and allowing the water current to circulate only when the jack was at work it was accomplished. The water current would completely cool the inner tube within a few minutes (as shown by the temperature at outlet), and it was at this period that the tube was loosened. The heat applied in this operation was not greater than that ordinarily used for heating the jacket to shrink it originally upon the tube.

The gun casing was examined and star-gauged with a view to deciding upon its use in the reconstruction of the gun. It was found to be in good condition, and the star-gauge measurements compared closely with those made at the South Boston Iron Works during the original construction of the gun, there being an average difference between the two independent sets of measurements of less than 0.001 inch.

The jacket was also carefully examined with the same view, and was found to be in good condition both outside and inside. The muzzle end of the bore was very slightly bell-shaped; but for the remainder of the bore the star-gauge measurements gave almost identically the same result as those made during the original construction of this tube. The exterior between "screw-head and first shoulder" was found to be slightly out of round, one diameter being about 0.004 inch greater than the other, and the greater diameter would not enter the casing, so that when the jacket was fitted to casing, this eccentricity was corrected.

The following parts were then made new for the gun:

1. Inner tube complete.
2. Muzzle collar.
3. Cast-iron breech-plug.
4. Securing pin through casing into tube; and these, with the casing, jacket, and copper vent piece belonging to the old piece, were used in reconstructing the gun.

CAUSE OF FAILURE OF TUBE NO. 39 (ORIGINAL) UNDER THE FIRING PROOF.

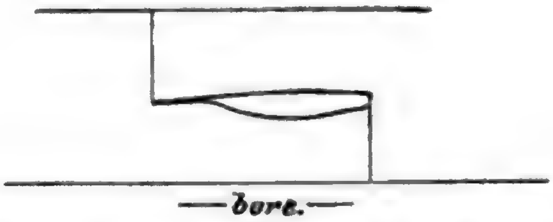
After the inner tube was extracted from the jacket, as previously described, it was cut up for examination. The accompanying drawing shows: Fig. 1, a section and interior elevation of the half tube cut by a plane coincident with the axis of the piece through the defect; and, Fig. 2, a cross-section of the wall of tube cut by a plane through the middle length of the defect. It is at once apparent that there existed a circular cavity about 1.1 by 0.12 inches in cross-section, extending wholly around the tube at the middle of the wall. This cavity is along the "lap" of the joint of two sections of the tube and was so left by the "press welding." A limited portion of the thin wall between this cavity and the bore of tube gave way under the powder pressure and caused the defect. The edges of this defect, as shown in Fig. 1, are slightly cracked, but not sufficiently to be marked on the impression which was taken of the defect at the firing ground.

The nature of the original defect in construction, *i. e.*, the existence of the *cavity*, is sufficiently serious to render highly important a knowledge of the cause of *its* existence. Unfortunately the explanation of this is still in doubt. The two remaining section-joints of this tube were also cut through for examination; one of them was perfect, and at the other there existed a cavity very similar to that at the joint where the defect occurred, only that it was much smaller and less dangerous, being about 0.6 by 0.04 inch in cross-section. In all of the joints the "butt welds" were without flaw.

Two different theories may be advanced to account for the existence of the original cavity: (1) That the joint was originally not a fit, that is, a space may have existed along the "lap" between the male and female portion of the joint when put into the "press furnace." This would be due to a mistake of the turner. (2) The cavity may be incident to the operation of "press welding."

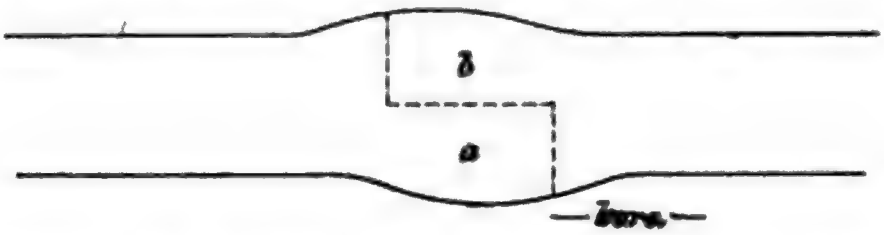
The opinions of persons connected with the foundry whose judgment in this matter is entitled to respect are about equally divided between the two theories.

The cross-section of the cavity shown in Fig. 1, with upper and lower lines nearly straight, favors the supposition that the space did exist there before the press welding; but, in that case, the male diameter would have been nearly 0.25 inch less than the female originally, which is not reasonable, for the two sections are held together by ***shrinkage alone*** when placed in the press furnace. The prescribed shrinkage is 0.02 inch on the diameter, and when two sections are first shrunk together a tie-rod is passed through the bore, but this is removed and a porter-bar, much smaller than the bore of sections, is passed through to carry them to the press furnace. A moderately tight fit even would probably serve to hold the two sections together during the manipulation subsequent to the removal of the tie-rod, but if the joint were loose the sections would almost certainly fall apart. Added to this, the whole purport of evidence on this point is such as almost precludes the supposition that any loose joints were put into the press furnace during construction under the current contract. The lower line of the cavity found at a second joint in this tube shows an inward curve, thus:



and indicates that the male part of the joint bulged inward during the press welding.

After the weld in the press furnace, under end compression, and with heat applied only in the vicinity of the section joint (extending some 9 inches on either side of its middle), the wall of metal is considerably bulged both inwards and outwards, thus:



The exterior of the tube is at once "lap welded" and straightened, at the same heat, under a steam hammer, during which operation the wall is unsupported within, and the inside bulge is left to be removed by the boring. The lip of the joint *a* is originally made 0.04 inch longer than *b*, so that *a* receives that amount of compression before the compression of *b* begins.

The above facts constitute good grounds for supposing that one or both of the lips may be carried away from the middle line in this bulging process, and offer a reasonable explanation for the existence of cavities in the wall along the lap joint. The fact that such cavities are found at some joints and not at others must be attributed in some way to more or less defective heats. The interior of the tube being possibly less heated than the outer portion, any tendency of the lip *a* to bulge inward as a whole would be more decided; at the same time, however, the arch should then offer a greater resistance to this movement.

It is evident, from the position of these cavities, that no means exist for determining whether or not they are present in a tube, unless the tube fails, as in the case of this No. 39. In any event, however, and whatever may be the cause of these cavities as found at *some* of the joints, it is evident from this experience that the present method of butt welding the sections of wrought-iron tubes is open to serious objections.

R. BIRNIE, Jr.,
Lieutenant of Ordnance.

Report of inspection of coiled wrought-iron tube No. 39, breech insertion, manufactured at the West Point Foundry, for 8-inch muzzle-loading rifle converted from 10-inch smooth-bore Rodman gun, under contract with the Chief of Ordnance, U. S. Army, dated June 12, 1884.

Subject of measurement.	Dimensions.		Variations.		Remarks.
	Prescribed.	Actual	Allowed.	Actual.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	
Total length of tube	147.66				Three inches surplus left at muzzle.
Total length of inner tube and jacket	140.41				
Projection of breech plug in rear of tube	7.25	7.25	±0.05		
Length of bore of tube	120.25				
Length of neck of tube	8.0				
Length of chase of tube	71.27				
Length of first reinforce of tube	8.73				
Length of second reinforce of tube	36.91				
Length of third reinforce of tube	7.0				
Length of fourth reinforce of tube	16.5				Left for threads.
Diameter of bore of tube	8.0	8.0	±0.03	.0	Not rifled.
Diameter of neck of tube	9.75	9.74	±0.03	−.01	
Diameter of chase of tube	10.8				Rough turned.
Diameter of first reinforce of tube	11.6				
Diameter of second reinforce of tube	13.6				
Diameter of third reinforce of tube	14.8				
Diameter of fourth reinforce of tube	15.6				
Length of muzzle collar	7.0				
Diameter of muzzle collar: interior	9.76	9.75	±0.03	−.01	
exterior	11.85				Rough turned.
Play between muzzle collar and neck of tube	0.01	0.01			
Incisions in muzzle collar: depth	0.875				
width	2.0				
Total length of jacket	60.41		±0.01		
Length of jacket in rear of inner tube	17.41	17.41	±0.05		
Length of jacket over inner tube	43.0	43.0	±0.05		
Interior diameter of jacket over inner tube	10.5	10.503	±0.01	+.003	
Exterior diameter of tube under jacket	10.503	10.505		+.002	
Corresponding shrinkage	0.003	0.002		−.001	
Total length of inner tube	123.0				
Radius of curve at bottom of bore of jacket	1.20	1.20	+0.01		
Radius of curve at bottom of tube	1.25	1.25			
Length of dowels (2) for securing tube to jacket.	2.0	2.0			
Diameter of dowels for securing tube to jacket.	0.75	0.75			
Thickness of wrought iron cup at bottom of tube.	2.75	2.75	±0.05		
Total length of cup	5.5	5.5	±0.05		
Diameters at interior of cup: top	7.0	7.0	±0.01		
bottom	4.6	4.6	±0.01		
Diameter of cup over threads	7.8	7.8	±0.01		The omissions in "actual dimensions" arise from the fact that the tube was finished and inserted in the casing at this foundry (authority, Chief of Ordnance, U. S. Army, dated July 12, 1884); it was therefore considered unnecessary to take the rough dimensions here omitted.
Pitch of thread on cup	3 to the inch.				
Total length of cast-iron breech plug	24.66	24.66	±0.01		
Length of breech plug within jacket	17.41	17.41	±0.05		
Length of thread on breech plug	16.41	16.41			
Diameter of breech plug over threads	7.0	7.0	±0.01		
Pitch of thread on breech plug	0.25	0.25			
Diameter of shoulder on breech plug	9.75	9.75			
Thickness of shoulder, including curved portion.	1.25	1.25			
Length of square at base of plug	6.0	6.0			
Side of square at base of plug	5.0	5.0			
Length of securing pin through shoulder on plug.	4.25	4.25			The finished dimensions appear on inspection report of gun No. 39 herewith.
Diameter of securing pin through shoulder on plug.	1.0	1.0			

Report of inspection of coiled wrought-iron tube No. 39, breech insertion, &c.—Continued.

PHYSICAL PROPERTIES.

Specimen.	Area of cross-section.	Density.	Tenacity.	Elastic limit.	Elongation per inch at rupture.	Remarks.
	Sq. inch.		*Lbs.*	*Lbs.*	*Inches.*	
Mean of 2 3-inch specimens ...	0. 25607	....	50, 500	23, 000	0. 24	A-iron 2¼ square for inner tube.
Mean of 2 3-inch specimens ...	0. 25967	....	48, 500	26, 000	0. 314	B-iron 2¼ square for jacket.
Mean of 2 3-inch specimens ...	0. 26057	....	49, 500	25, 000	0. 27	B-iron 4 x 3¼ x 3⅝ for jacket.
One specimen	1. 088	7. 2526	33, 286	....	....	Cast-iron for breech plug.

GENERAL REMARKS.

Hydraulic test of tube: Pressure of 120 pounds applied to inner tube when finished ready for assemblage with jacket.

This tube was made to replace original tube No. 39, accepted October 19, 1883, which failed under firing proof at United States Proving Ground, Sandy Hook, N. J.

The jacket of the old tube, as fitted to the gun casing at the South Boston Iron Works, was taken off (the old tube) without injury and used again for this tube. The inner tube and breech cup, the cast-iron breech plug, and the muzzle collar are new. The inner tube was made from a new lot of bar-iron (A iron), of which the physical qualities are given above. The physical qualities of the B-iron (in jacket) are taken from inspection report of tube No. 39.

Destination of tube: Finished and inserted in casing at West Point Foundry.

I certify that the foregoing report is correct, and that the 8-inch coiled wrought-iron tube therein specified has been accepted by me as conforming to the standards as to dimensions, quality of material, and character of workmanship prescribed by the Ordnance Department.

August 1, 1884

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

Record of measurements with star gauge and calipers of 8-inch muzzle-loading converted rifle breech insertion No. 39.

Distance from muzzle.	Diameter of bore of casing (mean).	Exterior diameter of tube (mean).	Play.	Diameter of bore before proof.	Distance from muzzle.	Diameter of bore of casing (mean).	Exterior diameter of tube (mean).	Play.	Diameter of bore before proof.
Inches.	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inch.*
1	....	9.746	....	8.003	62	10.505	10.492	.013	8.000
2	....	9.744	....	8.003	63	10.5045	10.492	.0125	8.000
3	....	9.742	....	8.000	64	10.5045	10.493	.0115	8.000
4	....	9.741	....	8.000	65	10.504	10.493	.011	8.000
5	....	9.739	....	8.000	66	10.504	10.493	.011	8.000
6	10.509	10.490	.019	8.000	67	10.504	10.493	.011	8.000
7	10.5095	10.489	.0205	8.000	68	....	....	....	8.000
8	10.509	10.489	.020	8.000	69	11.4905	11.475	.0155	8.000
9	10.5095	10.489	.0205	8.0005	70	11.4925	11.477	.0155	8.000
10	10.5085	10.489	.0195	8.000	71	11.492	11.475	.017	8.000
11	10.5085	10.489	.0195	8.0005	72	11.492	11.475	.017	8.000
12	10.5085	10.489	.0195	8.000	73	11.4915	11.476	.0155	8.000
13	10.5085	10.489	.0195	8.000	74	11.4915	11.477	.0145	8.000
14	10.5085	10.489	.0195	8.000	75	11.4915	11.478	.0135	8.000
15	10.510	10.490	.02	8.000	76	11.4915	11.478	.0135	8.000
16	10.5085	10.489	.0195	8.000	77	....	....	....	8.000
17	10.508	10.489	.019	8.000	78	....	....	....	8.000
18	10.5075	10.489	.0185	8.000	79	13.4885	....	....	8.000
19	10.507	10.490	.017	8.000	80	13.4905	....	....	8.000
20	10.507	10.489	.018	8.000	81	13.5015	13.4955	.006	8.000
21	10.507	10.491	.016	8.000	82	13.5015	13.4945	.007	8.000
22	10.508	10.490	.018	8.000	83	13.5015	13.494	.0075	8.000
23	10.5075	10.490	.0175	8.000	84	13.5015	13.494	.0075	8.000
24	10.508	10.491	.017	8.000	85	13.501	13.494	.007	8.000
25	10.508	10.490	.018	8.000	86	13.5015	13.494	.0075	8.000
26	10.508	10.490	.018	8.000	87	13.5015	13.4935	.008	8.000
27	10.508	10.490	.018	8.000	88	13.5015	13.495	.0065	8.000
28	10.508	10.491	.017	8.000	89	13.5015	13.495	.0065	8.000
29	10.508	10.491	.017	8.000	90	13.5015	13.4955	.006	8.000
30	10.508	10.491	.017	8.000	91	13.5015	13.496	.0055	8.000
31	10.507	10.492	.015	8.000	92	13.5015	13.496	.0055	8.000
32	10.5075	10.492	.0155	8.000	93	13.5015	13.496	.0055	8.000
33	10.507	10.492	.015	8.000	94	13.501	13.4955	.0055	8.000
34	10.507	10.492	.015	8.000	95	13.501	13.4955	.0055	8.000
35	10.507	10.492	.015	8.000	96	13.501	13.495	.006	8.000
36	10.507	10.492	.015	8.000	97	13.501	13.4945	.0065	8.000
37	10.507	10.492	.015	7.9995	98	13.501	13.495	.006	8.000
38	10.507	10.491	.016	8.000	99	13.5015	13.495	.0065	8.000
39	10.507	10.491	.016	8.000	100	13.5015	13.4945	.007	8.000
40	10.5065	10.491	.0155	8.000	101	13.5015	13.4945	.007	8.000
41	10.506	10.491	.015	8.000	102	13.5015	13.4945	.007	7.9995
42	10.506	10.491	.015	8.000	103	13.5015	13.495	.0065	8.000
43	10.506	10.492	.014	8.000	104	13.501	13.4955	.0055	8.000
44	10.506	10.492	.014	8.000	105	13.501	13.495	.006	8.000
45	10.506	10.491	.015	8.000	106	13.501	13.495	.006	8.000
46	10.506	10.491	.015	8.000	107	13.501	13.495	.006	8.000
47	10.506	10.492	.014	8.000	108	13.501	13.4955	.0055	8.000
48	10.506	10.491	.015	8.000	109	13.501	13.495	.006	8.000
49	10.506	10.491	.015	8.000	110	13.501	13.4955	.0055	8.000
50	10.506	10.491	.015	8.000	111	13.501	13.496	.005	8.000
51	10.506	10.492	.014	8.000	112	13.501	13.4955	.0055	8.000
52	10.506	10.492	.014	8.000	113	13.501	13.4945	.0065	8.000
53	10.506	10.492	.014	8.000	114	....	....	....	8.000
54	10.505	10.492	.013	8.000	115	14.696	14.6925	.0035	8.000
55	10.505	10.492	.013	8.000	116	14.696	14.6925	.0035	8.000
56	10.505	10.492	.013	8.000	117	14.696	14.6925	.0035	8.000
57	10.5045	10.492	.0125	8.000	118	14.696	14.6925	.0035	....
58	10.505	10.492	.013	8.000	119	14.696	14.6915	.0045	....
59	10.505	10.492	.013	8.000	120	14.696	14.690	.006	....
60	10.505	10.492	.013	8.000	121	14.696	14.6905	.0055	....
61	10.505	10.492	.013	8.000	122	14.6965	....	....	....

Record of measurements with star gauge and calibers of 8-inch muzzle-loading converted rifle breech insertion No. 39—Continued.

AFTER RIFLING TO BOTTOM OF GROOVES.

	Grooves.												Mean.	Depth of grooves.
	1 and 13.	2 and 14.	3 and 15.	4 and 16.	5 and 17.	6 and 18.	7 and 19.	8 and 20.	9 and 21.	10 and 22.	11 and 23.	12 and 24.		
4	8.146	8.151	8.150	8.151	8.154	8.149	8.147	8.151	8.151	8.150	8.165	8.148	8.151	0.0755
14	8.146	8.151	8.149	8.151	8.154	8.149	8.147	8.149	8.154	8.152	8.165	8.150	8.151	0.0755
24	8.148	8.150	8.148	8.148	8.153	8.149	8.148	8.148	8.149	8.149	8.162	8.150	8.150	0.0750
34	8.147	8.151	8.148	8.150	8.148	8.148	8.148	8.148	8.147	8.149	8.159	8.150	8.149	0.0745
44	8.146	8.147	8.148	8.149	8.149	8.147	8.149	8.149	8.147	8.150	8.160	8.150	8.149	0.0745
54	8.147	8.148	8.147	8.150	8.152	8.150	8.145	8.150	8.147	8.149	8.165	8.150	8.150	0.0750
64	8.147	8.148	8.147	8.151	8.152	8.151	8.147	8.150	8.148	8.150	8.166	8.150	8.150	0.0750
74	8.143	8.147	8.149	8.152	8.155	8.150	8.149	8.152	8.152	8.154	8.167	8.150	8.151	0.0755
84	8.155	8.150	8.153	8.154	8.156	8.152	8.150	8.156	8.153	8.155	8.162	8.150	8.154	0.077
94	8.155	8.150	8.156	8.159	8.154	8.154	8.152	8.154	8.152	8.152	8.168	8.158	8.157	0.0785
104	8.154	8.152	8.162	8.162	8.166	8.162	8.155	8.161	8.154	8.154	8.175	8.157	8.159	0.0795

Report of inspection and proof of 8-inch muzzle-loading rifle No. 39, converted (breech insertion) from 10-inch Rodman smooth-bore gun No. —, at the West Point Foundry, under contract of the Chief of Ordnance, dated June 12, 1883.

Subject of measurement.	Dimensions.		Variations.		Remarks.
	Prescribed.	Actual.	Allowed.	Actual.	
	Inches.	*Inches.*	*Inch.*	*Inch.*	
Maximum eccentricity of bore of casing	0.002	0.001	0.	....	
Distance from breech to first shoulder of casing.	21.6	21.6	±0.1	....	
Clearance at first shoulder between tube and casing.	0.05	0.065	±0.02	....	
Distance from breech to second shoulder of casing.	59.01	58.995	±0.1	−.015	
Clearance at second shoulder between tube and casing.	.05	.07	±0.02	+.02	
Distance from breech to third shoulder of casing.	67.51	67.595	±0.1	+.085	
Clearance at third shoulder between tube and casing.	0.	0.	0.	....	
Mean exterior diameter of finished tube from screw-head to first shoulder.	14.7	14.692	±0.1	−.008	
Corresponding mean diameter of bore of casing.	14.703	14.696	±0.1	−.007	
Corresponding play	0.003	0.004	0.	+.001	
Mean exterior diameter of finished tube from first shoulder to second shoulder.	13.5	13.495	±0.01	−.005	
Corresponding mean diameter of bore of casing.	13.503	13.501	±0.01	−.002	
Corresponding play	0.003	0.006	0.	+.003	
Mean exterior diameter of finished tube from second shoulder to third shoulder.	11.5	11.476	±0.1	−.024	
Corresponding mean diameter of bore of casing.	11.515	11.492	±0.1	−.023	
Corresponding play	0.015	0.016	0.	+.001	
Mean exterior diameter of finished tube from third shoulder to neck.	10.5	10.491	±0.1	−.009	
Corresponding mean diameter of bore of casing.	10.515	10.506	±0.1	−.009	
Corresponding play	0.015	0.015	0.	....	
Length of muzzle collar	5.0	5.0	±0.1	....	Original gun No. 39 on this contract was condemned under firing-proof at United States Ordnance Proving Ground, Sandy Hook, N. J. (See Lieut. C. W. Whipple's indorsement dated Sandy Hook, N. J., April 1, 1884.)
Length of recess in casing for muzzle collar.	5.65	5.575	±0.1	−.075	
Length of screw on muzzle-collar	3.15	3.15	±0.1	....	
Length of screw on recess in casing	3.275	3.275	±0.1	....	
Excess in length of screw on collar over that in recess.	0.125	0.125	±0.02	....	
Diameter of tube over neck	9.75	9.74	±0.03	−.01	
Interior diameter of muzzle collar	9.76	9.75	±0.03	−.01	
Corresponding play	0.01	0.01	0.	....	

Report of inspection and proof of 8-inch muzzle-loading rifle No. 39—Continued.

Subject of measurement.	Dimensions.		Variations.		Remarks.
	Prescribed.	Actual.	Allowed.	Actual.	
Diameter of muzzle collar across threads	11.75	11.75	±0.03	....	By authority of the Chief of Ordnance, U. S. Army, dated July 1 1884, the present gun has been completed at the foundry and replaces the original gun of same number. The cast-iron casing of original gun has been used again *without alteration*; also the copper vent piece. The original wrought-iron jacket has been altered only by slight fitting on outside between "screw head and first shoulder of finished tube." The following parts are new: 1. Wrought-iron inner tube and breech cup. 2. Wrought-iron muzzle collar. 3. Cast-iron breech plug. 4. Securing pin through casing.
Diameter of recess in casing	11.76	11.76	±0.03	....	
Play between collar and casing	0.01	0.01	0.	....	
Thickness of collar	1.0	1.0	±0.01	....	
Pitch of thread on collar	0.5	0.5	0.	....	
Length of screw on jacket (from tangent at base).	14.2	14.12	±0.05	−.08	
Pitch of screw on jacket	2.50	2.50	0.	....	
Diameter of jacket across threads	15.5	15.5	±0.05	....	
Corresponding diameter of casing	15.505	15.505	±0.05	....	
Corresponding play	0.005	0.005	0.	....	
Length of bore of tube	117.25	117.20	±0.02	−.05	
Length of rifled portion of bore	107.25	107.20	±0.2	−.05	
Diameter of bore across lands	8.0	8.0	±0.03	....	
Width of grooves	0.6982	0.6982	±0.01	....	
Width of lands	0.349	0.349	±0.01	....	
Number of grooves and lands	24.0	24.0	....	....	
Depth of grooves	0.075	0.0755	±0.005	+.0005	
Lands rounded with radius of	0.01	0.01	....	....	
Grooves filleted with radius of	0.02	0.02	....	....	
Pitch of rifling	1 in 30 ft.	1 in 30 ft.	0.	....	
Diameter of vent	0.2	0.2	±0.005	....	
Diameter of vent-bushing	0.98	0.98	±0.01	....	
Axis of vent from bottom of bore	4.50	4.50	±0.01	....	
Axis of vent to left of vertical plane through axis of bore.	2.50	2.50	±0.01	....	
Length of securing pin	6.20	6.20	±0.01	....	
Diameter of securing pin	1.5	1.5	±0.005	....	
Distance of securing pin from muzzle	60.0	60.0	±0.2	....	

Weight of gun.. 15,965 pounds.

Physical properties: (See inspection report of coiled wrought-iron tube No. 39 (duplicate) for 8-inch muzzle-loading rifle, breech insertion.)

I certify that the following report is correct, and that the 8-inch rifle therein specified has been accepted by me as conforming to the standards as to dimensions, quality of material, and character of workmanship prescribed by the Ordnance Department.

August 2, 1884.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

POWDER PROOF.

No. of fire.	Time.		Powder.		Projectile.		Elevation, in degrees.	Pressure lbs. per sq. in. of bore, Rodman.
	Month.	Day.	Kind.	Weight.	Kind.	Weight.		
				Pounds.		*Pounds.*		
1	August	30	Du Pont's hexagonal, E. V. M. density, 1.750; Gran. 72.	35	Butler (old)	180	0.	28,000
2	August	30		35	....do......	181	0.	29,000

ENLARGEMENT OF BORE AFTER POWDER PROOF.

Inches from muzzle.	Original diameter of bore.	Diameter of bore after firing.	Total enlargement.	Play of tube.	Enlargement after deducting play of tube.	Remarks.
	Inches.	*Inches.*	*Inch.*	*Inch.*	*Inch.*	
106	8.002	8.008	0.006	0.006	0.0000	
88	8.002	8.009	0.007	0.0065	0.0005	
74	8.002	8.014	0.012	0.0145	0.0000	Greatest enlargement.
50	8.002	8.004	0.002	0.015	0.0000	

I certify that the 8-inch rifle above specified has endured satisfactorily the powder proof prescribed by the Ordnance Department.

Place of proof: Sandy Hook Proving Ground.

C. W. WHIPPLE,
Lieutenant of Ordnance, Proof Officer.

Star-gauging of 8-inch muzzle-loading converted rifle No. 39, breech insertion.

Inches from muzzle.	Original diameter of bore.	Diameter after two rounds.	Inches from muzzle.	Original diameter of bore.	Diameter after two rounds.
	Inches.	*Inches.*		*Inches.*	*Inches.*
106	8. 002	8. 008	64	8. 002	8. 005
105	8. 002	8. 008	62	8. 002	8. 004
104	8. 002	8. 008	60	8. 002	8. 004
103	8. 002	8. 008	58	8. 002	8. 004
102	8. 002	8. 009	56	8. 002	8. 005
101	8. 002	8. 009	54	8. 002	8. 004
100	8. 002	8. 009	52	8. 002	8. 004
99	8. 002	8. 008	50	8. 002	8. 004
98	8. 002	8. 008	48	8. 002	8. 004
97	8. 002	8. 008	46	8. 002	8. 003
96	8. 002	8. 008	44	8. 002	8. 003
95	8. 002	8. 008	42	8. 002	8. 002
94	8. 002	8. 008	40	8. 002	8. 002
93	8. 002	8. 008	38	8. 002	8. 002
92	8. 002	8. 007	36	8. 002	8. 002
91	8. 002	8. 007	34	8. 002	8. 002
90	8. 002	8. 007	32	8. 002	8. 002
89	8. 002	8. 008	30	8. 002	8. 002
88	8. 002	8. 009	28	8. 002	8. 002
87	8. 002	8. 009	26	8. 002	8. 003
86	8. 002	8. 010	24	8. 002	8. 003
85	8. 002	8. 010	22	8. 002	8. 003
84	8. 002	8. 010	20	8. 002	8. 003
83	8. 002	8. 010	18	8. 003	8. 003
82	8. 002	8. 010	16	8. 003	8. 003
81	8. 002	8. 009	14	8. 003	8. 003
80	8. 002	8. 008	12	8. 003	8. 003
78	8. 002	8. 006	10	8. 003	8. 003
76	8. 002	8. 011	8	8. 003	8. 003
74	8. 002	8. 014	6	8. 003	8. 003
72	8. 002	8. 014	4	8. 003	8. 003
70	8. 002	8. 010	2	8. 003	8. 003
68	8. 002	8. 008	1	8. 003	8. 003
66	8. 002	8. 006			

Pressure: First round, 28,000; second round, 29,000.

RECORD WITH TESTING MACHINE.

Specimen of Ulster tube iron marked A 7, taken with the fiber from lot of 2¼ inch square bars of A iron received May 12, 1884, at West Point Foundry.

[Length of specimen between shoulders: Original, 3.00 inch; after rupture, 3.774 inches. Diameter of specimen: Original, 0.571 inch; after rupture, 0.432, 0.428 inch; mean, 0.430 inch.]

Weight applied.	Measurements under stress—length.	Measurements relieved from stress—length.	Weight applied.	Measurements under stress—length.	Measurements relieved from stress—length.
Pounds.			*Pounds.*		
256. 1	. 221	. 221	6, 914. 7	. 237	. 233
512. 2	. 221	. 221	7, 170. 8	. 237	. 234
768. 3	. 221	. 221	7, 426. 9	. 239	. 236
1, 024. 4	. 221	. 221	7, 683. 0	. 244	. 241
1, 280. 5	. 221	. 221	7, 939. 1	. 253	. 249
1, 536. 6	. 221	. 221	8, 195. 2	. 256	. 253
1, 792. 7	. 221	. 221	8, 451. 3	. 267	. 264
2, 048. 8	. 221	. 221	8, 707. 4	. 277	. 273
2, 304. 9	. 222	. 221	8, 963. 5	. 282	. 277
2, 561. 0	. 222	. 221	9, 219. 6	. 292	. 287
2, 817. 1	. 222	. 221	9, 475. 7	. 305	. 301
3, 073. 2	. 222	. 221	9, 731. 8	. 309	. 304
3, 329. 3	. 222	. 221	9, 987. 9	. 326	. 321
3, 585. 4	. 222	. 221	10, 244. 0	. 335	. 330
3, 841. 5	. 222	. 221	10, 500. 1	. 361	. 355
4, 097. 6	. 222	. 221	10, 756. 2	. 364	. 359
4, 353. 7	. 223	. 221	11, 012. 3	. 368	. 362
4, 609. 8	. 223	. 221	11, 268. 4	. 406	. 399
4, 865. 9	. 223	. 221	11, 524. 5	. 411	. 404
5, 122. 0	. 223	. 221	11, 780. 6	. 444	. 439
5, 378. 1	. 223	. 221	12, 036. 7	. 451	. 444
5, 634. 2	. 224	. 221	12, 292. 8	. 498	. 490
5, 890. 3	. 224	. 221	12, 548. 9	. 507	. 499
6, 146. 4	. 224	. 222	12, 805. 0	. 587	. 581
*6, 402. 5	. 235	. 232	13, 061. 1	. 776	. 765
6, 658. 6	. 236	. 232	13, 317. 2	. 995	....

* The record is reliable up to the elastic limit; at 24,000 pounds per square inch too much pressure was accidentally applied.

Specimen taken from end of bar included in lot of iron (different bar from A7).

Tested at United States Ordnance proving ground, Sandy Hook, N. J., May 24, 1884.

Tested by—

C. W. WHIPPLE,
Lieutenant of Ordnance.

Table of deduced results.

Weight per square inch of original area.	Extension per inch in length.	Successive extension per in. in length.	Restoration per inch in length.	Successive restoration per in. in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	....	....	....	....	....	....
* * *						
9,000	.0003⅓	.0003⅓	.0003⅓	.0003⅓	....	....
10,000	.0003⅓	.0.	.0003⅓	0.	....	....
11,000	.0003⅓	0.	.0003⅓	0.	....	....
12,000	.0003⅓	0.	.0003⅓	0.	....	....
13,000	.0003⅓	0.	.0003⅓	0.	....	....
14,000	.0003⅓	0.	.0003⅓	0.	....	....
15,000	.0003⅓	0.	.0003⅓	0.	....	....
16,000	.0003⅓	0.	.0003⅓	0.	....	....
17,000	.0006⅔	.0003⅓	.0006⅔	.0003⅓	....	....
18,000	.0006⅔	0.	.0006⅔	0.	....	....
19,000	.0006⅔	0.	.0006⅔	0.,	....	....
20,000	.0006⅔	0.	.0006⅔	0.	....	....
21,000	.0006⅔	0.	.0006⅔	0.	....	....
22,000	.001	.0003⅓	.001	.0003⅓	....	....
23,000	.001	0.	.001	0.	....	....
24,000	.001	0.	.0006⅔	−.0003⅓	.0003⅓	.0003⅓
25,000	.0046⅔	.0036⅔	.001	+.0003⅓	.0036⅔	.0033⅓
26,000	.005	.0003⅓	.0013⅓	+.0003⅓	.0036⅔	0
27,000	.0053⅓	.0003⅓	.0013⅓	0.	.004	.0003⅓
28,000	.0053⅓	0.	.001	−.0003⅓	.0043⅓	.0003⅓
29,000	.006	.0006⅔	.001	0.	.005	.0006⅔
30,000	.0076⅔	.0016⅔	.001	0.	.0066⅔	.0016⅔
31,000	.0106⅔	.003	.0013⅓	+.0003⅓	.0093⅓	.0026⅔
32,000	.0116⅔	.001	.001	−.0003⅓	.0106⅔	.0013⅓
33,000	.0153⅓	.0036⅔	.001	0.	.0143⅓	.0036⅔
34,000	.0186⅔	.0033⅓	.0013⅓	+.0003⅓	.0173⅓	.003
35,000	.0203⅓	.0016⅔	.0016⅔	+.0003⅓	.0186⅔	.0013⅓
36,000	.0236⅔	.0033⅓	.0016⅔	0.	.022	.0033⅓
37,000	.028	.0043⅓	.0013⅓	−.0003⅓	.0266⅔	.0046⅔
38,000	.0293⅓	.0013⅓	.0016⅔	+.0003⅓	.0276⅔	.001
39,000	.035	.0056⅔	.0016⅔	0.	.0333⅓	.0056⅔
40,000	.038	.003	.0016⅔	0.	.0363⅓	.003
41,000	.0466⅔	.0086⅔	.002	+.0003⅓	.0446⅔	.0083⅓
42,000	.0476⅔	.001	.0016⅔	−.0003⅓	.046	.0013⅓
43,000	.049	.0013⅓	.002	+.0003⅓	.047	.001
44,000	.0616⅔	.0126⅔	.0023⅓	+.0003⅓	.0593⅓	.0123⅓
45,000	.0633⅓	.0016⅔	.0023⅓	0.	.061	.0016⅔
46,000	.0743⅓	.011	.0016⅔	−.0006⅔	.0726⅔	.0116⅔
47,000	.0766⅔	.0023⅓	.0023⅓	+.0006⅔	.0743⅓	.0016⅔
48,000	.0923⅓	.0156⅔	.0026⅔	+.0003⅓	.0896⅔	.0153⅓
49,000	.0953⅓	.003	.0026⅔	0.	.0926⅔	.003
50,000	.122	.0266⅔	.002	−.0006⅔	.12	.0273⅓
51,000	.185	.063	.0036⅔	+.0016⅔	.1813⅓	.0613⅓
52,000	.258	.073	Broke.	....	....	....

GENERAL SUMMARY.

Specific gravity		
Hardness		
Elastic limit	pounds	23,000
Extension per inch at elastic limit	inch	0.001
Ultimate resistance per square inch of original area	pounds	52,000
Ultimate extension per inch	inch	0.258
Ratio of elastic to ultimate resistance		2.26
Original area of cross-section	square inch	0.25607
Contraction in area at fracture	per cent	43.3
Ultimate resistance per square inch of fractured area	pounds	91,700
Position of fracture		one-fourth distance from upper shoulder.
Character of surface		uniform fibrous.

RECORD WITH TESTING MACHINE.

Specimen of Ulster tube iron, marked A 7, taken with the fiber from lot of 2¼-inch square bars of A iron, received May 12, 1884, at West Point Foundry.

[Length of specimen between shoulders: Original, 3.00 inches; after rupture, 3.669 inches. Diameter of specimen: Original, 0.571 inch; after rupture, 0.416, 0.432 inch; mean, 0.424 inch.]

Weight applied.	Measurements under stress—length.	Measurements relieved from stress—length.	Weight applied.	Measurements under stress—length.	Measurements relieved from stress—length.
Pounds.	*Inch.*	*Inch.*	*Pounds.*	*Inch.*	*Inch.*
256. 1	. 273	. 273	6, 658. 6	. 286	. 283
512. 2	. 273	. 273	5, 914. 7	. 291	. 287
768. 3	. 273	. 273	7, 170. 8	. 296	. 293
1, 024. 4	. 273	. 273	7, 426. 9	. 300	. 296
1, 280. 5	. 273	. 273	7, 683. 0	. 308	. 304
1, 536. 6	. 273	. 273	7, 939. 1	. 316	. 312
1, 792. 7	. 273	. 273	8, 195. 2	. 326	. 321
2, 048. 8	. 274	. 273	8, 451. 3	. 336	. 332
2, 304. 9	. 274	. 273	8, 707. 4	. 345	. 340
2, 561. 0	. 274	. 273	8, 963. 5	. 350	. 345
2, 817. 1	. 274	. 273	9, 219. 6	. 365	. 362
3, 073. 2	. 274	. 273	9, 475. 7	. 372	. 366
3, 329. 3	. 274	. 273	9, 731. 8	. 391	. 386
3, 585. 4	. 274	. 273	9, 987. 9	. 397	. 392
3, 841. 5	. 274	. 273	10, 244. 0	. 425	. 420
4, 097. 6	. 274	. 273	10, 500. 1	. 433	. 427
4, 353. 7	. 275	. 273	10, 756. 2	. 461	. 455
4, 609. 8	. 275	. 273	11, 012. 3	. 478	. 471
4, 865. 9	. 275	. 273	11, 268. 4	. 501	. 494
5, 122. 0	. 275	. 273	11, 524. 5	. 535	. 528
5, 378. 1	. 276	. 273	11, 780. 6	. 572	. 564
5, 634. 2	. 276	. 273	12, 036. 7	. 617	. 608
5, 890. 3	. 277	. 273	12, 292. 8	. 679	. 670
6, 146. 4	. 277	. 275	12, 548. 9	. 942	....
6, 402. 5	. 281	. 278			

Specimen taken from end of bar included in lot of iron (different bar from A 7).
Tested at United States Ordnance Proving Ground, Sandy Hook, N. J., May 24, 1884.
Tested by—

C. W. WHIPPLE,
Lieutenant of Ordnance

Table of deduced results.

Weight per square inch of original area.	Extension per inch in length.	Successive extension per inch in length.	Restoration per inch in length.	Successive restoration per inch in length.	Permanent set per inch in length.	Successive permanent set per inch in length.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1,000	....	....	....	....	....	....
• • •						
8,000	.0003⅓	.0003⅓	.0003⅓	.0003⅓	....	....
9,000	.0003⅓	0.	.0003⅓	0.	....	....
10,000	.0003⅓	0.	.0003⅓	0.	....	....
11,000	.0003⅓	0.	.0003⅓	0.	....	....
12,000	.0003⅓	0.	.0003⅓	0.	....	....
13,000	.0003⅓	0.	.0003⅓	0.	....	....
14,000	.0003⅓	0.	.0003⅓	0.	....	....
15,000	.0003⅓	0.	.0003⅓	0.	....	....
16,000	.0003⅓	0.	.0003⅓	0.	....	....
17,000	.0006⅔	.0003⅓	.0006⅔	.0003⅓	....	....
18,000	.0006⅔	0,	.0006⅔	0.	....	....
19,000	.0006⅔	0.	.0006⅔	0.	....	....
20,000	.0006⅔	0.	.0006⅔	0.	....	....
21,000	.001	.0003⅓	.001	.0003⅓	....	....
22,000	.001	0.	.001	0.	....	....
23,000	.0013⅓	.0003⅓	.0013⅓	.0003⅓	....	....
24,000	.0013⅓	0.	.0006⅔	−.0006⅔	.0006⅔	.0006⅔
25,000	.0026⅔	.0013⅓	.001	+.0003⅓	.0016⅔	.001
26,000	.0043⅓	.0016⅔	.001	0.	.0033⅓	.0016⅔
27,000	.006	.0016⅔	.0013⅓	+.0003⅓	.0046⅔	.0013⅓
28,000	.0076⅔	.0016⅔	.001	−.0003⅓	.0066⅔	.002
29,000	.009	.0013⅓	.0013⅓	+.0003⅓	.0076⅔	.001
30,000	.0116⅔	.0026⅔	.0013⅓	0.	.0103⅓	.0026⅔
31,000	.0143⅓	.0026⅔	.0013⅓	0.	.013	.0026⅔
32,000	.0176⅔	.0033⅓	.0016⅔	+.0003⅓	.016	.003
33,000	.021	.0033⅓	.0013⅓	−.0003⅓	.0196⅔	.0036⅔
34,000	.024	.003	.0016⅔	+.0003⅓	.0223⅓	.0026⅔
35,000	.0256⅔	.0016⅔	.0013⅓	−.0003⅓	.024	.0016⅔
36,000	.0306⅔	.005	.001	−.0003⅓	.0296⅔	.0056⅔
37,000	.033	.0023⅓	.002	+.001	.031	.0013⅓
38,000	.0393⅓	.0063⅓	.0016⅔	−.0003⅓	.0376⅔	.0066⅔
39,000	.0413⅓	.002	.0016⅔	0.	.0396⅔	.002
40,000	.0506⅔	.0093⅓	.0016⅔	0.	.049	.0093⅓
41,000	.0533⅓	.0026⅔	.002	+.0003⅓	.0513⅓	.0023⅓
42,000	.0626⅔	.0093⅓	.002	0.	.0606⅔	.0093⅓
43,000	.0683⅓	.0056⅔	.0023⅓	+.0003⅓	.066	.0053⅓
44,000	.076	.0076⅔	.0023⅓	0.	.0736⅔	.0076⅔
45,000	.0873⅓	.0113⅓	.0023⅓	0.	.085	.0113⅓
46,000	.0996⅔	.0123⅓	.0026⅔	+.0003⅓	.097	.012
47,000	.1146⅔	.015	.003	+.0003⅓	.1116⅔	.0146⅔
48,000	.1353⅓	.0206⅔	.003	0.	.1323⅓	.0206⅔
49,000	.223	.0876⅔	Broke.		....	....

GENERAL SUMMARY.

Specific gravity		
Hardness		
Elastic limit	pounds	23,000
Extension per inch at elastic limit	inch	0.00133
Ultimate resistance per square inch of original area	pounds	49,000
Ultimate extension per inch	inch	0.223
Ratio of elastic to ultimate resistance		2.13
Original area of cross-section	square inch	0.25607
Contraction in area at fracture	per cent	44.86
Ultimate resistance per square inch of fractured area	pounds	88,876
Position of fracture		one-fourth distance from lower shoulder.
Character of surface		uniform fibrous.

APPENDIX 27*c*.

CONSTRUCTION REPORT OF FIFTY 8-INCH RIFLES CONVERTED FROM 10-INCH RODMAN SMOOTH BORE GUNS BY LINING WITH WROUGHT-IRON TUBES, BREECH INSERTION.

BY LIEUT. H. D. BORUP, ORDNANCE DEPARTMENT.

Under date of June 12, 1884, the Chief of Ordnance contracted for fifty 8-inch rifles converted from 10-inch Rodman smooth-bore guns by lining with a wrought-iron tube (breech insertion). The tubes were fabricated at the West Point Foundry, while the casings were prepared and the parts assembled by the South Boston Iron Works.

A detailed description of this method of conversion, with the reasons therefor, is given by Colonel Crispin, U. S. Army, in the Report of the Chief of Ordnance for 1878, page 351.

THE CASING.

This consists of a 10-inch Rodman smooth-bore. Placed in the lathe, the cutter pierces the breech to the size of the bore. It is then reversed and bored through to a diameter of 10.5 inches, and the recess for muzzle collar and thread cut. Reversed again it is first counter-bored to 11.5 inches diameter for a distance of 68.16 inches, then to 13.5 inches for a distance of 16.66 inches.

The breech screw is cut, and the casing is ready for inspection. About a month elapsed after the first casing entered the mill before it was finished; afterwards the average out-put was one per week. Four lathes were kept in operation.

THE TUBES.

The tubes fabricated at the West Point foundry are formed of coiled wrought-iron bars, surrounded by a jacket of the same material, commencing at 77 inches from the muzzle and extending about 16.66 inches beyond the breech. The base of the tube is closed with a cup made of tube iron scrap, against the rear face of which is the breech plug of cast iron screwed into the jacket.

They were received at this foundry rough-turned, and finished bored. Each tube was first rifled, and then turned with special reference to the casing it was to enter, the diameter of which had been previously determined by the star gauge.

The muzzle collar, also made of tube scrap, was fabricated at the West Point Foundry, and received here rough-turned. It was finished and the screw thread cut here.

ASSEMBLING OF THE PARTS.

After the tube was finished it was calipered carefully at every inch of its length to see if the play between it and the casing did not exceed that allowed. It was then inserted in the casing, which had previously been placed on a carriage, muzzle inclining downwards. The shoulders of the bore were covered with red lead, so that it could be seen if contact between the forward shoulders of the tube and casing was obtained, and at the same time if the clearance between the others was preserved, the amount of which was afterwards measured. As a rule several trials were required. This being accomplished satisfactorily, contact between the end of the muzzle collar and shoulder of neck of tube, was similarly determined (the end of collar being smeared with lead). The piece was then transferred to the lathe and faced, after which the old vents were closed with wrought-iron plugs, and the holes for the securing pin, and for the copper bushing containing the new vent, drilled.

The piece was carefully inspected at all its stages and when finished was marked and sent to Sandy Hook.

One gun, No. 112, West Point Foundry, was spoiled by counter-boring the 11.5 inch diameter for too great a distance. The South Boston Iron Works offered to replace this gun with one of their own, which was of identical dimensions with those of the United States. Its tenacity and density as originally determined by specimens taken from the sinking head gave 32,204 pounds and 7.231 respectively. This was accepted by the Chief of Ordnance. A specimen taken from the breech before piercing showed a tenacity of 36,959 and a density of 7.2663. It sometimes happens that the first thread on the screw of jacket is exposed by the ratchet on the breech of the casing originally made for the elevating bar. To avoid this it would be well to increase the length of the short cylinder in rear of the thread. The details of inspection showing principal dimensions, both prescribed and actual, together with the variations therefrom, will be found in the inspection reports.

In Table A the inspection reports have been consolidated so as to show the prescribed dimensions and variations, together with the number of guns in which the last was actually exceeded, and the maximum, minimum, and mean amount of such excess, *i.e.*, the difference between the actual variation and that prescribed. An effort is also made in the column of remarks to show where the variations prescribed might be advantageously changed.

TABLE A.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	Number of guns in which variations exceeded that allowed.	Maximum variations in excess of that allowed.	Minimum variations in excess of that allowed.	Mean variation in excess of that allowed.	Remarks.
	Inches.	*Inch.*		*Inch.*	*Inch.*	*Inch.*	
Maximum eccentricity of bore of casing.	.002	0.	6	.003	.001	.00133	At two points one gun exceeded the prescribed allowance by .003 inch, the others exceeded it by .001, inch, at one point only.
Distance from breech to first shoulder of casing.	21.6	±.1	......	......	......	......	Allowance is sufficient.
Clearance at first shoulder between tube and casing.	.05	±.02	8	.11	.01	.024	Do.
Distance from breech to second shoulder of casing.	50.01	±.1	......	......	......	......	Do.
Clearance at second shoulder between tube and casing.	.05	±.02	14	.04	.01	.015	Do.

TABLE A—Continued.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	Number of guns in which variations exceeded that allowed.	Maximum variations in excess of that allowed.	Minimum variations in excess of that allowed.	Mean variations in excess of that allowed.	Remarks.
	Inches.	*Inch.*		*Inch.*	*Inch.*	*Inch.*	
Distance from breech to third shoulder of casing.	67.51	±.1	3	.08	.04	.06	Allowance is sufficient.
Clearance at third shoulder between tube and casing.	0.	0.	......	......	......	......	Do.
Mean exterior diameter of finished tube from screw head to first shoulder.	14.7	±.1	......	......	......	......	The allowed variation can be reduced to .01 inch.
Corresponding mean diameter of bore of casing.	14.703	±.1	......	......	......	......	
Corresponding play	.003	0.	34	.005	.001	.00226	A variation of .002 inch might be permitted.
Mean exterior diameter of finished tube from first shoulder to second shoulder.	13.5	±.01	......	......	......	......	Allowance is sufficient.
Corresponding mean diameter of bore of casing.	13.503	±.01	......	......	......	......	
Corresponding play	.003	0.	32	.006	.001	.00206	A variation of .002 inch might be permitted.
Mean exterior diameter of finished tube from second shoulder to third shoulder.	11.5	±.1	......	......	......	......	The allowed variation can be reduced to .02 inch.
Corresponding mean diameter of bore of casing.	11.515	±.1	......	......	......	......	
Corresponding play	.015	0.	2	.001	.001	.001	Allowance is sufficient.
Mean exterior diameter of finished tube from third shoulder to neck.	10.5	±.1	......	......	......	......	The actual variation in no case exceeded .02 inch, to which the prescribed might be reduced.
Corresponding mean diameter of bore of casing.	10.515	±.1	......	......	......	......	
Corresponding play	.015	0.	13	.006	.001	.00223	Allowance is sufficient.
Length of muzzle collar	5.	±.1	21	.28	.01	.09095	These vary with length of neck of tube; attention is mainly directed to obtaining contact, and excess of thread on collar over that in casing; an allowance of .2 inch would cover all cases.
Length of recess in casing for muzzle collar.	5.65	±.1	......	......	......	......	Allowed variation is sufficient.
Length of screw on muzzle collar	3.15	±.1	19	.2	.01	.03684	Do.
Length of screw on recess in casing.	3.	±.1	1	.033	.033	.033	Do.
Excess in length of screw on collar over that in recess.	.15	±.02	48	.19	.03	.08485	This might be increased to .1 inch.
Diameter of tube over neck	9.75	±.03	......	......	......	......	Could be reduced to .01 inch.
Interior diameter of muzzle collar	9.76	±.03	......	......	......	......	
Corresponding play	.01	0.	16	.007	.001	.00231	Allowance is sufficient.
Diameter of muzzle collar across threads.	11.75	±.03	2	.034	.005	.0195	Might be reduced to .02 inch.
Diameter of recess in casing	11.76	±.03	1	.001	.001	.001	
Play between collar and casing	.01	0.	9	.033	.001	.00588	Allowed variation is sufficient.
Thickness of collar	1.	±.01	......	......	......	......	Do.
Pitch of thread on collar	.5	0.	......	......	......	......	
Pitch of screw on jacket	2.5	0.	......	......	......	......	
Diameter of jacket across threads	15.5	±.05	......	......	......	......	Do.
Corresponding diameter of casing	15.505	±.05	......	......	......	......	
Corresponding play	.005	0.	3	.009	.004	.00633	Do.
Length of bore of tube	117.25	±.02	46	.29	.01	.11673	This varies with the length of the casing; a variation of .2 inch, same as for the rifling, might be allowed.
Length of rifled portion of bore	107.25	±.02	14	.27	.02	.11928	Allowed variation is sufficient.
Diameter of bore across lands	8.	±.03	......	......	......	......	
Width of grooves	6.982	±.01	......	......	......	......	
Width of lands	.349	±.01	......	......	......	......	
Number of grooves and lands	24.	......	......	......	......	......	

TABLE A—Continued.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	Number of guns in which variations exceeded that allowed.	Maximum variations in excess of that allowed.	Minimum variations in excess of that allowed.	Mean variation in excess of that allowed.	Remarks.
	Inches.	*Inch.*		*Inch.*	*Inch.*	*Inch.*	
Depth of grooves	.075	±.005	2	.0015	.001	.00125	Allowed variation is sufficient.
Lands rounded with radius of	.01						
Grooves filleted with radius of	.02						
Pitch of rifling	1 in 30 ft.	0.					
Diameter of vent	.2	±.005					Allowed variation is sufficient.
Diameter of vent-bushing	.98	±.01	1	.005	.005	.005	Do.
Axis of vent from bottom of bore	4.50	±.01	30	.08	.01	.03666	Although great care was taken in drilling this hole, it may be said that it was only accidentally that it came within the allowed variation. This should be increased.
Axis of vent to left of vertical plane through axis of bore.	2.50	±.01	20	.27	.01	.07096	The above remarks apply to this.
Length of securing pin	6.20	±.01	5	.10	.01	.05	Allowed variation is sufficient.
Diameter of securing pin	1.5	±.005	4	.046	.001	.024	Do.
Distance of securing pin from muzzle.	60.	±.02					Do.

APPENDIX 28.

REPORT ON THE MANUFACTURE AND INSPECTION OF 2½-INCH SMOOTH-BORE BRONZE LIFE-SAVING GUNS AND PROJECTILES (LYLE MODEL, 1877) AT THE WEST POINT FOUNDRY, CONTRACT OF DECEMBER 14, 1883; 100 GUNS AND 1,200 PROJECTILES (SERVICE NUMBERS OF GUNS FROM 201 TO 300, INCLUSIVE).

BY LIEUTENANT ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(5 plates.)

OFFICE OF INSPECTOR OF ORDNANCE, U. S. A.,
WEST POINT FOUNDRY,
Cold Spring, N. Y., August 20, 1884.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

GENERAL: I have the honor to transmit herewith a report of the manufacture and inspection of 135 2½-inch bronze life-saving guns (Lyle model, 1877), and 1,620 cast-iron projectiles for the same, at this foundry during the past year. One hundred of the guns, with 1,200 projectiles, were made for the Life-Saving Service and the remainder for the Revenue Marine Service.

The report, accompanied by five plates, includes a description of the methods of manufacture and inspection, with accessories, including instruments; the results of mechanical tests of the metal; the usual firing proof; and the extreme proof of one gun selected from the 35 last made. It also includes the results of the chemical analysis of ten samples by Capt. John Pitman, United States Ordnance, from different castings, and the mechanical tests (Appendix) of ten specimens, the same metal as the samples, made upon the testing-machine at Watertown Arsenal, which are considered especially instructive and important.

The conclusion reached is that 9 per cent. of tin is the best proportion for use under the method of manufacture at present pursued for these guns. Attention is invited to a change proposed (page 401) in the method of proof firing which, it is believed, will put the bore of the guns in condition to be not materially enlarged by pressures which may be anticipated in service.

Very respectfully, your obedient servant,

R. BIRNIE, JR.,
Lieutenant of Ordnance.

REPORT ON THE MANUFACTURE AND INSPECTION OF 2½-INCH SMOOTH-BORE BRONZE LIFE-SAVING GUNS AND PROJECTILES (LYLE MODEL, 1877) AT THE WEST POINT FOUNDRY, CONTRACT OF DECEMBER 14, 1883; 100 GUNS AND 1,200 PROJECTILES (SERVICE NUMBERS OF GUNS FROM 201 TO 300, INCLUSIVE).

Five years since, 200 guns and a number of projectiles of similar pattern were made at this foundry for the Life-Saving Service. A report upon the manufacture of the guns was made by Lieut. C. W. Whipple, Ordnance Department, who was then the resident inspector, and has been published in the Report of the Chief of Ordnance for 1879 (see also Ordnance Notes, No. 102). That report will be found especially valuable, since it treats of the steps taken to inaugurate the manufacture of these guns for the service, and as well for its detailed treatment of the subject. The object of the present writing will be to recount the current methods of manufacture and inspection, based upon the experience already gained, and to record such observations incident thereto as are deemed useful.

THE GUNS.

The guns are made of chill-cast bronze, containing approximately 9 per cent. of Banca tin and 91 per cent. of Lake Superior copper. Figs. 1–4, Plate I, give a drawing of the model, the principal parts and average dimensions of which are as follows:

Diameter of first reinforce	inches	5.5
Diameter of chase	do	4.5
Diameter of bore	do	2.5
Diameter of trunnions	do	2.0
Diameter of rimbases	do	2.8
Diameter of cascabel	do	1.5
Diameter of vent	do	0.2
Radius of breech	do	2.75
Radius of chamber	do	1.25
Length of first reinforce	do	9.1
Length of second reinforce	do	1.40
Length of chase	do	9.5
Length of bore, exclusive of chamber	do	18.75
Total length of bore	do	20.00
Length of trunnions	do	2.00
Length of rimbases	do	0.10
Length of cascabel	do	1.5
Distance of vent from bottom of bore	do	1.25
Distance between rimbases	do	5.70
Total length of piece	do	24.25
Weight of piece (average of 100)	pounds	114.33
Preponderance at 0.5 inch in rear of curve of breech (average of 100)	do	3.266

The several stages of the manufacture and inspection of the guns may be divided as follows:

1. The metals used for the castings.
2. Preparations for casting, to include the furnace and its accessories, and the molds.
3. The casting.
4. Tests of the metal of the sinking-head.

5. The firing proof, including the preparation of the gun for this proof.

6. Final finish and inspection.

And in general, in the rough casting or during the finishing processes, serious flaws or blow-holes may be found sufficient to cause the rejection of the piece, whatever may have been the results of the tests of the proof-bar.

The metals.—The ingot metals used for casting these guns were Lake Superior copper, from the Quincy Mining Company, and Banca tin, both of which are held in deservedly high repute, and are considered to be scarcely excelled in the market. The first casting was made from ingot metals alone. Subsequently the "sinking heads," which constituted about 42 per cent. of the weight of each casting,* and also the turnings, borings, and planings from the finishing shop, were used as part of the charge.

Preparations for casting.—A sketch of the furnace is shown, Fig. 3, Plate II. It is an ordinary brass-molders' furnace of an old pattern, and consists of a 24 inch cylinder of boiler-iron lined with fire-brick, resting upon cross-bars arranged at the back of the ash-pit, next to the stack. The top is covered with an iron plate provided with an opening having a movable cover for the passage of the crucible. The ash pit and draft are below the foundry floor, and the furnace is not provided with a damper. Two cylinders, each holding one crucible, are arranged side by side, and connected over the same ash-pit, but each cylinder has a separate flue. The two crucibles, having a capacity of about 155 pounds each, were used together for the casting of one gun. Two guns were generally cast about the same time, using a second furnace of similar design.

The mold, Figs. 2 and 3, Plate II, consists of the cast-iron "chill," the sand-head, and the runner-box. The cast-iron chill is made in two equal parts, divided longitudinally; the abutting faces of these parts are finished and fitted. The flanges are bored for six strong bolts on each side, and four smaller holes for guiding-pins in the assemblage. The whole base of the chill is also finished, and when in use rests upon a leveled plate set at the bottom of a pit about 30 inches deep, in order to level the mold and bring the top of it to a convenient height above the foundry floor for pouring. The weight of the chill (1,440 pounds) makes it nearly 4.7 times that of the casting, including the sinking-head (304 pounds), and more than 8 times that of the gun proper in the rough (176 pounds). The cavity in the chill conforms in general to the exterior of the finished gun; allowing for the contraction, it leaves the casting about 0.25 inch surplus over all sides. The trunnion spaces are beveled on the upper sides to facilitate the escape of impurities, which would naturally collect there, and also to leave a larger surplus of metal to be removed from those parts, as has been found by experience to be necessary.† The chase portion of the chill is slightly contracted

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*After being cut from the guns, the heads were taken to the forge *moderately* heated and broken in pieces under the hammer. The parts were used indiscriminately for subsequent castings, but care was taken to throw out the scoria or very porous metal, which in some castings was found about the top of the head.

†In casting larger calibers of bronze guns in Russia, Colonel Lavrov has arranged his trunnion spaces with very long bevels, both above and below, but especially below, since it was found that blow-holes were formed in the casting just below the trunnions as cast (his guns are cast breech up), and this was supposed to be due to that upon the solidification and first contraction of the casting the trunnions were called

towards the top.* The cavity in the chill extends about 10.5 inches above the muzzle of the gun proper and forms the lower portion of the sinking head, which is completed by the sand-head, 10 inches high above. The sand-head is molded in a cast-iron flask of simple pattern. The mold is not dried, and is renewed for each casting. The runner-box, of oblong shape, is made of sheet-iron; it is partly filled and rounded on the interior with a packing of clay, which is coated with black-lead wash, and may be used for a large number of castings by repairing the surface and renewing the wash. The metal enters through a small orifice in the middle of the box directly over the center of the mold.

The advantages of this over the old method of casting in sand-molds have been repeatedly shown. The castings are much freer from blowholes, the metal is denser, more uniform, and superior in elastic properties and strength. The metal within the chill solidifies very quickly, leaving that within the sand-head in a molten state; the sand-head thus performs two important functions, (1) as a "feeder" to supply the contraction of the casting as the lower portion solidifies, and (2) as a weight which supplies the pressure necessary to produce a sound casting of good quality. The purely mechanical advantages of the chill-mold consist in the facilities afforded for making any number of castings of a given form, and that without renewing the mold for each casting, as when using sand; the sand-head, of simple form and easily made, is the only portion of mold requiring renewal.

CASTING THE GUNS.

This most important part of the manufacture needs to be conducted with every possible care in all its details. It requires a careful and experienced workman, who should be prompt to take advantage of every opportunity for improvement by noting the outcome of castings in which, either by accident or design, slight changes in the details of treatment may have been introduced.

The operations under this head embrace—

1. *The charge.*—The average weight of metal used per casting was 307 pounds, nearly. For the first casting, where ingot metals only were used, the charge was 281.5 pounds of copper and 28 pounds of tin, or 9.05 per cent. of the latter metal. Each metal was divided into two as nearly equal parts as possible for the charges of the separate crucibles.

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upon to support the weight of the casting, so the metal just beneath them "gave" to a certain extent and became unsound. By his arrangement of bevels the whole casting may sink at once as it contracts (see Lieutenant Whipple's report above cited; also, Notes on Construction of Ordnance, No. 21). In the present instance only one casting of the 104 made was found to be seriously affected in this way. It appears probable that this would not have occurred if the trunnion spaces had been beveled after the manner of the Russian chills.

* The reason for this construction is not plain, and in the presence of the generally excellent results obtained criticism is perhaps unnecessary. But Colonel Lavrov's experience has shown that it is inadvisable to have a contracted section of the mold situated in this way, since it will solidify first and vitiate one of the principal good effects of the sand-head, viz, the "feeding." It is probable that the slightness of the contraction in the present case prevented much ill effect, yet several of the castings did not sink at all at the upper surface on cooling. Again, however, the slope given to the chase in this way may facilitate its shrinkage and thus improve the quality of the metal in that part of the gun, even without the assistance of the sinking-head above.

In all the subsequent castings the charge, which was made up partly of heads, turnings, &c., was arranged to have approximately a like percentage of tin, and was divided in the same way. The charges for all the castings are given in the general table which follows, but the percentages of tin can only be regarded as approximate, since there was no means for determining the exact percentage of tin contained in the heads, &c. The estimate given in the table is based upon 9 per cent., or very nearly that supposed to be contained in the original charge.[*]

2. *Heating the chill.*—For the first casting of the day the chill was placed, with a lid on top to close the interior, upon a truck, and run into an oven heated by a wood fire, where it was usually left about one hour and fifteen minutes. It was then taken out and arranged in the casting pit. Its ordinary temperature was probably about 250°. Usually two castings daily were made in one chill, the second from two to three hours after the first. The chill was not reheated in the oven, but on the removal of the first casting was replaced in the pit with the sand-head in place and the top covered. Its temperature then became somewhat lower than for the first casting, but as a rule was more uniform.

3. *Melting.*—After the fires were well started the crucibles containing the charge of copper (or copper and bronze) were placed in the furnace.[†] When the copper began to melt, showing a surface of liquid metal, charcoal was thrown into the crucible to cover the surface for the purpose of retaining the heat and retarding oxidation. The average time of "melting copper" was one hour and forty-five minutes, depending upon the fire and the manipulation of the furnace. For the morning casting the lid of the furnace was usually kept closed, but for the afternoon casting it was frequently left partly open for some time after the crucible was introduced, to suit the convenience of the work, but always closed to make the heat as great as possible for the actual melting of the copper. A second supply of charcoal was thrown upon the surface of the metal as soon as the contents were melted. With some of the castings an interval of time was allowed at this point before adding the tin, during which period the top of the furnace was usually left open. In adding the tin the broken ingots were placed in the crucibles, a third supply of charcoal then thrown upon the surface, and the contents well stirred with an iron rod. The interval between this and withdrawing the crucibles was also very unequal, but if left in the furnace the top of the latter was wholly or partly removed, to gradually cool the contents. When taken from the furnace the contents of the crucibles were well stirred and then carefully skimmed for pouring. Then, with a number of the castings, a quantity of planings—sometimes as much as 8 pounds—were put into one or both (usually only one) of the crucibles, with intent to correct what appeared to be unusual fluidity or overheat of the metal.

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[*] Authorities are wanting to supply this knowledge for chill castings. Such analyses as have been made are, so far as known, very limited, but go to show that the segregation of tin towards the head is very slight, if any. The rapidity of solidification in the chill makes this reasonable (see page 397). And, on the other hand, we have always a disproportionate loss of tin from oxidation; for, "although two or three parts of copper are lost in this way to one of tin, yet the latter is present in so much smaller quantity that continued remeltings of the same alloy will show an increase in the percentage of copper and a constant decrease in the percentage of tin remaining." (Encyclopædia of Chemistry, J. B. L. & Co., Phila. 1877, Vol. I, page 583.)

[†] When turnings, planings, &c., sometimes sufficient of themselves to fill the crucible, were used they were put in first, covered with a layer of charcoal and melted down before the introduction of the ingot copper and bronze.

4. *Pouring*.—The two crucibles were poured together from opposite sides of the runner-box. No arrangement was made for skimming in this operation, but care was taken to keep the box well filled, so that the dross, if any, would float on the surface and enter the mold last of all. When one crucible was hotter than the other its contents were held back to supply the sinking-head. After the pouring, charcoal was at once thrown upon the top and the doors of the foundry opened on both sides to assist the cooling.

As a rule, the best castings were those which shrunk the most and very rapidly. The shrinkage of the head was sometimes almost immediate; in other cases there was no shrinkage, which invariably marked a casting below the average or one subsequently condemned. The metal solidified in a few minutes, and the casting could be removed from the chill within twenty minutes after the pouring.

Both of the chills used became covered with cracks on the interior, especially about the trunnions and the breech, after a few castings had been made; in each one the crack through the trunnion cavities soon extended through the walls of the chills. Each day, after casting, the interior of the chill was carefully repaired by hammering the cracks shut and coating the whole surface with a wash of black lead. The same two chills were used throughout, without any apparent deterioration of the castings due to the cracks.

A number of the castings were weighed in the rough and gave an average loss of 2.5 pounds from the weight of charge, or, in other words, a loss of weight equal to about 0.8 of 1 per cent.

TESTS OF THE METAL.

A specimen bar of the prescribed dimensions, taken from the lower portion of the sinking-head (see Figs. 1 and 2, Plate III), should give a tenacity of not less than 36,000 pounds per square inch. The head is separated at the muzzle of the gun and the specimen piece taken out from the base close to the outer surface, either with a hollow boring tool or by cutting off the lower portion of the head and slotting out the specimen piece; the first method requires the least expenditure of labor. When finished, as shown in Fig 2, Plate III, the bar is weighed for density and then tested for tenacity and ultimate extension.

In these tests the least stress of the machine, 5,000 pounds, is first applied, and increased stresses (increasing by 100 pounds of added weights) are afterwards continuously applied until the bar breaks. The distance between gauge-marks is measured before and after the test, to determine the elongation after fracture; two diameters at right angles are similarly measured to compute the reduction of area. The behavior of the specimen under test will be referred to following the general table of results.

THE FIRING PROOF, AND PREPARATIONS THEREFOR.

The exterior of the gun is rough-finished all over, leaving a surplus of 0.04 of an inch on the diameter, except for the trunnions, which are completely finished. The bore is pierced by a twist drill having a diameter of about 2.25 inches, and is finished for the proof by reaming out to a diameter of 2.45 inches and shaping the bottom to a half sphere of the same diameter. The vent is made by drilling a hole 0.2 inch in diameter through the wall of the piece in the portion afterwards reamed out for the vent piece.

The carriage used in the proof of these guns weighed 96 pounds. It consisted of two solid cheeks made of heavy oak plank, held together by several cross-bolts and two transoms, one under the breech of the piece and one under the muzzle; wooden wedges were placed on these and supported the extremities of the piece when fired. An iron strap fastened along the top of each cheek contained the trunnion-beds, which were set at a distance apart closely approximating that between the rimbases of the gun. Cap squares fastened by bolts were also provided, but the iron-work was simply rough-forged. In order to protect the finished trunnions in the firing, a closely fitting steel sleeve about 0.5 inch in thickness was placed on each before mounting the piece.

The proof projectile is a solid cylinder of cast-iron weighing about 18 pounds, and turned to fit the bore closely.

Each gun was proved by firing three rounds with a charge of 8 ounces of Hazard navy cannon powder and one of the above projectiles. The projectiles were fired into a sand butt, recovered, and used for firing several rounds. Fifty-nine projectiles were used up or lost in firing 306 rounds. The carriage was allowed a free recoil, and with the gun went sliding and tumbling usually about 30 feet to the rear up a slight incline.

After the proof the trunnions were carefully examined for displacement and the bore gauged with one of the proof projectiles. None of the guns showed any marked failing, and as that fact was developed after a number of the guns had been fired, it was decided to dispense with the extreme proof of one gun, which was at first contemplated.

FINAL FINISH AND INSPECTION.

The essential implements for gauging the correct finish of the gun, except calipers for exterior diameters, are shown in Plate III, Figs. 3 to 9, inclusive. They are—

1. *Profile templet for exterior length* (Fig. 3), *which may be made wood.*—It is accurately constructed to drawing, and when laid on the gun shows the corrections of the different parts of the length from the cascabel to the muzzle.

2. *Combined chase and breech templet* (Fig. 4), *made of metal.*—This is constructed to abut against the finished trunnion. On one side it gives the length of the chase, the two slopes of the second reinforce to the rimbase, and the width of the latter. The other side gives similarly the profile of the breech portion of the gun, to include the width of the rimbase in rear of the trunnion.

3. *Cross-trunnion gauge* (Fig. 5), *of metal.*—It determines the length of the trunnions, the distance between the rimbases, and of the cross profile of the body of the gun.

4. *Gauge for position of vent, bottom and length of bore* (Fig. 7).—A thin plate of metal is rounded at the end with a beveled edge to fit the bottom of the bore in a plane passing through its axis. The half circle is incomplete at the sides, in order to pass freely through the bore. A chamfered hole is made at the center of the head, to come beneath the

vent and receive the point of the vent gauge, if the vent be true, when the latter is introduced. The remainder of the metal piece is reduced in width and extends back to the face of the muzzle, imbedded in a strip of wood, which latter is itself supported by a couple of rounded studs arranged to center the gauge. The correct muzzle line is scored upon an offset of the metal. The strip of wood is also made to fit the bore accurately for 3 inches from the muzzle, in order to center the implement laterally.

5. *Trunnion gauges* (Fig. 6).—The minimum gauge has an interior diameter of 2.0 inch, and should not pass over the trunnions; the maximum gauge is 0.02 of an inch larger, and should pass freely.

6. *Vent gauge* (Fig. 8).—Made to pass closely through the vent, which should be 0.2 inch in diameter.

7. *Cylinder gauge for bore* (Fig. 9).—A carefully finished steel cylinder, 2.5 inches in diameter and 5 inches long, which should pass air-tight to the bottom of the cylindrical portion of the bore. This also serves to test the straightness of the bore.

The trunnions are finished and gauged before any other part of the gun; the combined chase and breech gauge, in the hands of the workman, with calipers, serves to finish the parts that can be turned; the circular portions between the rimbases are finished in a shaping-machine and the curves of the rimbases by hand, to conform to the profile given by the cross-trunnion gauge. The bore is finished after the machine work on the exterior. No variation from an air-tight fit for the cylinder gauge is allowed; the boring must consequently be done with great care, and it frequently occurs that although the gauge may enter when the bore is warm from the boring, yet it will not enter when the latter is cold, so that the gun has to be returned to the lathe.

The vent piece, the details of which are shown in Fig. 5, Plate I, is assembled last of all. It is made of wrought copper, the proper size in the rough being a bar of 1 inch diameter. From this the vent piece is rough-shaped in the smith-shop by heating the end of the bar to a low red-heat. The forged piece is first drilled for the vent, as it is very difficult to prevent a deviation of the drill. The exterior finish is then given to the vent piece about the vent as a center.

Marks are placed upon the muzzle, right trunnion, and right rimbase of the gun, as shown in Figs. 2 and 4, Plate I. Those upon muzzle are: The United States Register number of the piece, above; the place of fabrication, at the left; the year, at the right; and the inspector's initials below. The foundry number of the piece is placed upon the right rimbase, and the letters U. S. L. S. S. upon the end of the right trunnion. As this foundry has made all the guns of this model now in service, the two numbers correspond. The numbers of the guns supplied under this contract range from 201 to 300, inclusive.

BURNING ON NEW TRUNNIONS.

Two castings otherwise good were found to have defective trunnions. The method given in Lieut. C. W. Whipple's report was followed to replace them by new ones. With one of the pieces this was entirely successful; with the other, one of the new trunnions was found to be defective, and a second attempt was made to burn one on, in which the casting was rendered useless. The pouring of the hot metal fused not only the part about the junction of the trunnion with the gun, but passed entirely through the wall of the piece to the bore, which it partly filled, and held therein an iron rod which had been heated and inserted to warm the metal. The pouring was continued too long.

GENERAL RESULTS.

The records of all the castings, the results of mechanical tests of one specimen from the sinking-head of each, together with the numbers, weight, and breech preponderance of the guns, are given in the following table:

TABLE A.—*Record of casting, register number, weight*

Order of castings.	Finished gun.			Casting.									
				Metals used.						Time.			
					Bronze.								
	United States register number.	Weight.	Breech preponderance.	Ingot copper.	Heads.	Turnings, boring, and planings.	Ingot tin.	Percentage of tin.	Total weight.	Furnace charged to copper molted.	Tin added to metal taken from furnace.	Metal drawn to casting.	Shrinkage of upper surface in mold.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*	*H. M.*	*M.*	*M.*	*Inch.*
1	207	114.5	3.25	281.5	....	....	28.0	9.05	309.5	....	....	....	....
2	202	115.0	3.00	226.0	65.0	....	21.75	9.03	312.75	....	....	....	....
3	220	114.0	3.25	226.0	48.0	12.0	22.0	8.9	308.0	1.55	6	5	....
4	225	111.75	3.50	226.0	60.0	....	22.5	9.4	308.5	1.55	18	5	....
5	227	114.75	3.00	226.0	60.0	....	20.875	8.56	306.875	1.15	8	5	....
6	204	115.5	3.375	226.0	60.0	....	20.875	8.56	306.875	1.15	16	5	....
7	221	111.5	3.25	178.0	70.0	40.0	15.0	8.22	303.0	1.41	4	3	....
8	240	112.75	3.25	210.0	35.0	40.0	20.5	8.92	305.5	1.30	4	3	....
9	215	114.75	3.125	211.0	77.0	....	20.5	8.89	308.5	.47	11	3	....
10	214	115.0	3.125	177.0	111.0	....	16.5	8.70	304.5	1.00	8	3	2.0
11	208	111.75	3.25	219.0	44.0	26.0	21.25	8.88	310.25	1.45	4	4	2.0
12	229	114.5	3.875	213.0	45.0	30.0	20.7	8.80	308.7	2.00	4	4	....
13	205	115.25	2.875	219.5	65.5	....	20.625	8.68	305.625	1.22	8	5	2.25
15	211	114.0	3.00	206.0	60.0	23.0	19.5	8.74	308.5	2.00	2	4	1.0
16	216	113.5	3.375	180.0	60.0	50.0	17.0	8.76	307.0	1.52	8	3	1.0
17	210	114.75	3.25	204.0	66.0	19.0	19.45	8.79	308.45	1.25	5	3	1.0
18	200	115.0	3.375	202.0	67.5	20.0	19.3	8.8	308.8	1.36	15	2	1.75
19	238	112.0	3.125	210.0	50.5	30.0	20.2	8.83	310.7	1.50	7	3	0.75
20	213	115.0	3.125	208.0	54.5	27.5	20.0	8.83	310.0	1.53	3	3	1.875
21	243	115.0	3.125	210.0	50.5	30.0	20.2	8.83	310.7	2.15	2	3	1.0
22	203	113.75	3.25	206.0	54.5	28.5	19.75	8.82	308.75	2.20	5	7	1.0
23	222	114.5	3.00	210.0	50.5	30.0	20.2	8.83	310.7	1.55	3	7	1.25
24	231	114.5	3.25	200.0	70.0	20.0	19.1	8.80	309.1	2.15	6	3	1.5
25	230	115.0	2.875	208.0	58.0	24.0	20.0	8.83	310.0	2.05	5	3	1.75
26	223	115.25	3.25	200.0	67.0	23.0	19.25	8.84	309.25	2.12	3	3	....
27	212	112.0	3.00	210.0	50.5	30.0	20.2	8.83	310.7	1.40	5	6	0.75
28	218	114.5	3.125	224.0	41.0	20.0	21.75	8.88	306.75	1.40	5	4	1.5
29	206	114.75	3.125	224.0	40.0	20.0	21.75	8.88	305.75	1.50	5	5	0.75
30	249	115.0	3.00	224.0	40.0	20.0	21.75	8.88	305.75	2.00	3	4	1.5
31	201	115.0	3.25	224.0	30.0	30.0	21.75	8.88	305.75	1.35	3	5	1.875
32	217	114.75	3.125	210.0	45.0	30.0	20.3	8.80	305.8	1.35	5	3	1.875
33	226	115.25	3.125	224.0	60.0	....	21.5	8.81	305.5	2.00	5	3	2.25
34	237	114.75	3.00	206.0	80.0	....	19.5	9.03	305.5	1.55	4	6	1.5
35	244	113.5	3.125	200.0	70.0	20.0	19.1	8.8	309.1	1.35	3	5	1.5
36	236	114.5	3.25	200.0	60.0	30.0	19.1	8.8	309.1	1.42	8	5	1.5
37	233	115.5	3.25	200.0	70.0	20.0	19.1	8.8	309.1	1.42	8	5	1.5
38	234	115.5	3.25	200.0	70.0	20.0	19.1	8.8	309.1	2.05	4	4	1.75
39	232	114.0	3.125	210.0	35.0	40.0	20.5	8.92	305.5	1.30	2	6	2.0
40	255	115.25	3.19	210.0	35.0	40.0	20.5	8.92	305.5	1.52	7	3	1.75
41	219	114.5	3.375	160.0	....	130.0	14.0	8.45	304.0	1.40	12	3	1.25
42	241	115.5	3.25	190.0	....	100.0	17.75	8.69	307.75	1.40	13	5	1.75
43	235	114.5	3.375	160.0	....	130.0	14.75	8.68	304.75	1.25	15	6	2.0
44	224	114.5	3.125	160.0	....	130.0	14.75	8.68	304.75	1.30	2	6	1.75
45	296	114.5	3.19	160.0	....	130.0	14.75	8.68	304.75	1.55	3	2	1.75
46	262	115.5	3.25	160.0	....	130.0	14.75	8.68	304.75	1.50	6	9	1.75
47	228	114.0	3.5	160.0	130.0	....	14.25	8.53	304.25	1.30	15	4	1.25
48	248	115.0	3.25	160.0	130.0	5.0	14.25	8.54	309.25	1.30	5	6	1.5
49	239	115.25	3.125	160.0	130.0	7.0	14.5	8.61	311.5	2.0	7	4	3.0
50	250	114.75	3.25	160.0	130.0	7.0	14.5	8.61	311.5	1.55	11	4	1.25
51	242	115.0	3.25	60.0	130.0	5.0	14.25	8.54	309.25	1.45	8	5	1.75

breech preponderance, and physical properties of the guns.

Casting.	Test of specimens from sinking head.					
Condition of metal when poured.	Apparent specific gravity.	Tenacity of original cross-section.	Ultimate extension per inch.	Reduction in area at fracture.	Tenacity of reduced cross-section.	
		Lbs.	*Inch.*	*P. ct.*	*Lbs.*	
	8.8086	50,111	0.3308	29.75	71,333	Ingot metals alone used.
	8.8837	54,984	0.4812	39.44	90,794	Slow fire until copper began to melt.
	8.8578	49,185	0.3923	34.67	75,288	Borings, &c., placed in bottom of crucible.
	8.5762	44,387	0.3385	23.93	58,350	Blow-holes in head; poured too slow.
	8.6297	47,586	0.4692	34.47	72,614	Used "sand-heads" of castings Nos. 1 and 2.
	8.9104	50,712	0.3886	33.39	76,480	Do.
	8.3908	36,989	0.1846	19.72	46,075	No shrinkage of head.
	8.624	41,788	0.3077	25.56	56,137	Do.
	8.6114	42,788	0.4138	31.39	62,362	Do.
	8.8529	53,185	0.4981	43.66	94,393	Shrinkage almost immediate.
	8.5103	42,188	0.2605	24.91	56,183	Shrunk 1.5 inches very rapidly.
Crucible No. 1, hot; No. 2, moderate.	8.7705	44,787	0.2682	29.61	63,630	No shrinkage; crucible No. 1 melted thirty minutes before No. 2.
	8.8809	49,786	0.4615	33.65	75,038	Shrunk 2 inches very rapidly.
Moderately hot	8.6959	45,387	0.2692	26.21	61,506	Interchange of metal in crucible just before pouring.
	8.7867	49,185	0.3808	28.66	68,950	
	8.8567	53,584	0.4769	32.11	78,932	
	8.8608	55,184	0.5615	42.14	95,376	
Hot	8.6571	45,587	0.3231	22.83	59,075	Shrinkage almost immediate.
Moderately hot	8.8727	52,385	0.5000	39.15	86,086	
do	8.8751	54,584	0.5346	40.32	91,455	Melted fifteen minutes before adding tin.
	8.8199	45,987	0.3846	30.45	66,122	Melted twenty minutes before adding tin.
Moderately cool	8.7844	48,786	0.3977	27.92	67,684	Metal considered too hot when taken from furnace; cooled in air.
Crucible No. 1, cool; No. 2, moderately hot.	8.8078	49,185	0.4286	31.91	72,233	
do	8.8423	48,986	0.4154	41.76	84,110	Melted twenty minutes before adding tin.
do	8.8651	52,385	0.5038	45.46	96,040	
Hot	8.5888	38,789	0.2038	18.98	47,847	Unusually hot metal; cool chill; blow-holes in casting.
	8.8692	53,984	0.5602	40.90	91,337	Chill cool; unimportant blow-holes.
	8.7762	46,387	0.3462	26.75	63,415	Melted twenty-five minutes before adding tin.
	8.8231	52,385	0.5346	43.00	91,896	Melted twenty-seven minutes before adding tin.
Hot	8.7756	46,187	0.3142	28.03	64,172	Metal considered overhot.
do	8.7839	47,586	0.3000	23.38	62,110	Do.
Cool	8.8864	54,784	0.5115	44.22	98,213	Exceptional shrinkage.
Moderately hot	8.8879	55,584	0.4291	33.25	83,265	Melted twenty-three minutes before adding tin.
do	8.7017	40,588	0.2500	27.71	56,144	Chill hotter than usual.
do	8.8283	45,987	0.4000	32.01	67,637	Do.
Moderately cool	8.8663	51,385	0.4308	36.88	81,407	Chill moderate heat.
do	8.8808	53,584	0.6000	47.9	102,850	Do.
Crucible No. 1, cool; No. 2, moderately hot.	8.8063	45,587	0.323	28.56	63,810	Chill extra heat.
Cool	8.8439	53,384	0.5385	33.04	79,725	Do.
do	8.6345	42,788	0.3962	37.77	68,760	Melted thirty minutes before adding tin.
do	8.9012	48,985	0.4538	35.07	75,445	Do.
Very fluid; cool	8.8352	52,385	0.5077	34.06	79,444	
Cool	8.8486	50,785	0.4846	35.78	79,080	Metal quite fluid.
Quite fluid; cool	8.8602	54,581	0.5885	45.33	99,855	Melted twenty minutes before adding tin.
do	8.8296	47,586	0.3769	25.02	63,465	Do.
Very thin; cool.	8.5845	44,387	0.2615	21.95	56,870	
Crucible No. 1, cool; No. 2, moderately hot.	8.8539	49,580	0.4615	38.66	80,836	5 pounds bronze added to one pot after skimming to cool metal.
Moderately hot	8.8725	53,784	0.6154	43.84	95,800	7 pounds bronze added; shrunk hollow in center.
do	8.8429	54,784	0.4654	26.32	74,350	7 pounds bronze added; shrunk hollow with scoria about edges.
Crucible No. 1, very cool nd dull; No. 2, lively.	8.8201	48,585	0.3962	29.19	68,616	5 pounds bronze added; even shrinkage.

TABLE A.—*Record of casting, register number, weight, breech*

Order of castings.	Finished gun.			Casting.									
				Metals used.						Time.			
					Bronze.								
	United States register number.	Weight.	Breech preponderance.	Ingot copper.	Heads.	Turnings, boring, and planings.	Ingot tin.	Percentage of tin.	Total weight.	Furnace charged to copper melted.	Tin added to metal taken from furnace.	Metal drawn to casting.	Shrinkage of upper surface in mold.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*	*H. M.*	*M.*	*M.*	*Inch.*
52	271	114.5	3.375	160.0	130.0	5.0	14.25	8.54	309.25	1.40	5	5	1.75
53	260	115.5	3.375	160.0	130.0	1.5	14.25	8.53	305.75	2.0	8	3	2.0
54	247	115.5	3.125	160.0	130.0	....	14.25	8.53	304.25	1.30	6	5	2.25
55	254	115.5	3.44	160.0	130.0	3.0	14.25	8.53	307.25	1.20	7	3	1.5
56	297	113.75	3.125	160.0	130.0	3.0	14.25	8.53	307.25	1.10	11	6	1.0
57	245	114.75	3.25	160.0	130.0	....	14.25	8.53	304.25	1.50	8	3	2.0
58	275	115.25	3.125	160.0	130.0	....	14.25	8.53	304.25	1.30	7	5	2.25
59	246	112.0	3.5	160.0	130.0	8.0	14.25	8.54	312.25	1.40	2	7	0.625
60	256	113.75	3.625	160.0	130.0	5.0	14.25	8.54	309.25	1.50	10	3	0.625
61	252	114.5	2.875	160.0	130.0	....	14.25	8.53	304.25	2.05	6	4	1.0
62	270	111.0	1.625	160.0	130.0	....	14.25	8.53	304.25	1.50	10	6	1.0
64	264	114.25	3.0625	160.0	130.0	6.0	14.25	8.54	310.25	1.35	6	5	1.5
65	292	113.5	3.5	160.0	130.0	....	14.25	8.53	304.25	1.40	32	5	0.5
66	201	114.75	3.5	160.0	100.0	4.0	14.25	8.54	308.25	1.30	37	6	0.75
67	293	113.5	3.375	160.0	130.0	7.0	14.25	8.54	311.25	1.35	10	7	0.625
68	253	114.75	3.25	160.0	130.0	7.0	14.55	8.54	311.25	1.20	12	8	1.5
69	287	114.25	3.125	160.0	130.0	....	14.25	8.53	304.25	1.50	35	6	1.25
70	251	114.75	3.25	160.0	130.0	6.0	14.25	8.54	310.25	1.50	35	8	1.25
71	291	114.5	3.25	160.0	130.0	6.0	14.25	8.54	310.25	1.25	6	6	2.375
72	278	114.25	3.25	160.0	130.0	....	14.25	8.53	304.25	1.30	16	9	1.25
74	280	113.5	3.25	....	303.0	3.0	....	9.0	306.0	....	[illegible]	[illegible]	1.25
75	258	112.5	3.44	160.0	130.0	8.0	14.25	8.54	312.25	1.17	18	6	0.75
76	269	115.0	3.25	160.0	130.0	....	14.25	8.53	304.25	1.24	6	5	1.75
77	286	114.75	3.125	160.0	130.0	....	14.25	8.53	304.25	2.10	34	7	1.25
78	279	114.5	3.25	160.0	130.0	....	14.25	8.53	304.25	2.05	47	6	1.25
79	284	113.0	3.375	160.0	130.0	....	14.25	8.53	304.25	1.40	21	8	0.75
80	257	114.0	3.375	160.0	130.0	....	14.25	8.53	304.25	1.40	13	10	1.25
81	289	114.75	2.875	204.0	85.0	....	19.5	8.80	308.5	2.10	30	6	1.25
82	290	114.5	2.875	204.0	85.0	....	19.5	8.80	308.5	1.50	37	6	1.25
83	281	113.75	3.125	160.0	130.0	....	14.25	8.53	304.25	1.25	10	10	1.25
84	268	115.0	3.25	160.0	130.0	....	14.25	8.53	304.25	1.25	10	10	2.0
85	265	115.25	3.19	160.0	130.0	....	14.25	8.53	304.25	2.0	43	5	1.5
86	266	114.5	3.25	176.0	114.0	....	16.5	8.73	306.5	1.45	46	4	1.5
87	294	114.25	3.25	204.0	68.0	17.0	19.25	8.73	308.25	1.30	8	7	1.75
88	298	113.5	3.31	204.0	68.0	17.0	19.25	8.73	308.25	1.40	6	7	1.75
89	274	115.25	3.19	204.0	84.0	....	19.25	8.73	307.25	2.0	38	3	1.75
90	283	114.5	3.25	204.0	84.0	....	19.25	8.53	307.25	1.40	43	4	1.5
91	267	109.5	3.625	160.0	130.0	....	14.25	8.53	304.25	1.20	23	7	......
92	277	114.75	3.125	160.0	130.0	....	14.25	8.53	304.25	1.35	15	8	1.75
93	273	114.5	3.375	160.0	130.0	....	14.25	8.53	304.25	1.30	15	7	1.5
94	282	115.25	3.375	160.0	130.0	....	14.25	8.53	304.25	1.40	34	6	1.75
95	259	114.5	3.25	160.0	130.0	....	14.25	8.53	304.25	1.20	15	5	1.0
96	295	113.5	3.25	160.0	130.0	....	14.25	8.53	304.25	1.45	6	4	1.75

preponderance, and physical properties of the guns—Continued.

Casting.	Test of specimens from sinking head.					
Condition of metal when poured.	Apparent specific gravity.	Tenacity of original cross-section.	Ultimate extension per inch.	Reduction in area at fracture.	Tenacity of reduced cross-section.	
		Lbs.	*Inch.*	*P. ct.*	*Lbs.*	
Crucible No. 1, dull; No. 2, lively.	8.8055	47,586	0.4654	40.02	79,343	5 pounds bronze added; even shrinkage.
....	8.8803	48,186	0.4461	41.38	82,195	1.5 pounds bronze added; shrunk hollow in center with scoria.
Very cool	8.8893	53,584	0.5231	28.98	75,450	Hollow shrinkage; considerable scoria.
Crucible No. 1, cool; No. 2, moderately hot.	8.7885	50,786	0.4731	35.68	78,956	Sand heads principally; 3 pounds bronze added to one crucible.
......do	8.8134	44,587	0.4000	34.37	67,932	Lower heads principally; bronze added as above.
Crucible No. 1, cool; No. 2, very cool.	8.8598	54,784	0.5923	49.07	107,540	Sand heads principally; considerable scoria.
Crucible No. 1, cool; No. 2, lively.	8.8582	50,385	0.4423	37.38	80,457	Lower heads principally; considerable scoria.
Crucible No. 1, cool; No. 2, moderately hot.	8.5257	44,587	0.3448	28.03	61,950	8 pounds bronze added to cool metal; chill cool.
Cool	8.6033	44,187	0.3462	33.14	66,090	Do.
......do	8.7861	49,986	0.3654	32.42	73,967	Melted fifteen minutes before adding tin.
......do	8.6238	45,187	0.3410	29.20	63,820	Melted twelve minutes before adding tin.
......do	8.7426	45,387	0.4214	34.83	69,646	6 pounds bronze added to one crucible to cool metal.
......do	8.6713	50,585	0.5000	40.41	84,892	
Crucible No. 1, cool; No. 2, moderately cool.	8.7307	47,986	0.3962	24.37	63,446	4 pounds bronze added to one crucible.
Crucible No. 1, very cool; No. 2, moderate.	8.6648	45,187	0.3846	39.15	74,257	7 pounds bronze added to both crucibles.
Moderately cool	8.8291	54,784	0.5154	38.27	88,741	Do.
Very cool	8.8179	50,385	0.3500	21.73	64,373	Metal cooled in furnace.
......do	8.7713	55,184	0.4789	24.26	72,858	6 pounds bronze added to cool metal.
......do	8.8236	49,786	0.3577	24.87	65,825	Do.
Cooled to low temperature in air.	8.6591	46,186	0.3486	21.17	58,593	Allowed to cool in open air.
Very cool; low temperature in furnace.	8.7321	46,986	0.2692	21.40	60,115	Lower heads only; slow fire.
Cooled in air	8.5166	43,987	0.2962	26.42	59,784	8 pounds bronze added to molten metal, which was very liquid.
Moderately hot	8.8541	49,185	0.3846	25.89	66,364	No bronze added; poured at once after skimming.
Cooled in furnace	8.7978	53,384	0.5038	34.16	81,085	Melted thirty-four minutes before adding tin.
......do	8.8409	51,785	0.4846	27.07	71,003	Melted forty-seven minutes before adding tin.
Cool	8.5851	45,586	0.3486	23.60	59,670	Cooled partly in furnace and partly in air.
......do	8.7119	45,786	0.2538	19.16	56,637	Do.
So cool that portion did not run.	8.8750	52,584	0.3027	23.00	65,502	About 12 pounds metal remained i one crucible; head 2.5 inches short.
Moderately hot	8.8539	52,784	0.5769	47.72	100,900	
Cooled in air	8.7187	44,587	0.3346	35.48	69,103	
Crucible No. 1, moderately cool; No. 2, moderately hot.	8.8310	52,584	0.5241	43.47	93,017	
Very cool	8.8863	52,584	0.6846	56.72	121,490	Chill cooler than usual for second casting.
......do	8.8731	52,385	0.5019	43.66	92,973	Do.
Moderately cool	8.7929	47,986	0.3077	27.71	66,362	
......do	8.7646	47,186	0.3039	40.56	67,948	
Very cool	8.8817	51,185	0.5058	34.57	78,227	Metal cooled in furnace.
Crucible No. 1, cool; No 2, moderately hot.	8.8081	51,385	0.4692	25.89	69,331	Do.
Moderately cool	8.3634	42,187	0.3500	27.60	58,271	No shrinkage; chill extra hot.
Cool	8.8236	49,185	0.4269	31.10	71,385	Chill hot.
......do	8.8474	49,986	0.3846	25.56	67,150	
......do	8.8569	53,384	0.5538	31.71	78,160	
Very cool	8.6814	47,186	0.2797	21.28	61,342	Chill extra hot.
......do	8.7672	47,986	0.3716	32.53	71,088	Do.

TABLE A.—*Record of casting, register number, weight, breech*

Order of castings.	Finished gun.			Casting.									
				Metals used.						Time.			Shrinkage of upper surface in mold.
					Bronze.								
	United States register number.	Weight.	Breech-preponderance.	Ingot copper.	Heads.	Turnings, boring, and planings.	Ingot tin.	Percentage of tin.	Total weight.	Furnace charged to copper melted.	Tin added to metal taken from furnace.	Metal drawn to casting.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*	*H. M.*	*M.*	*M.*	*Inch.*
97	272	114. 75	3. 25	160. 0	130. 0	....	14. 25	8. 53	304. 25	1. 41	5	7	1. 25
98	263	115. 25	3 375	160 0	130. 0	....	14. 25	8. 53	304. 25	1. 50	32	6	1. 5
99	285	113. 75	3. 625	160. 0	130. 0	....	14. 25	8. 53	304. 25	1. 10	24	7	1. 75
100	276	115. 5	3. 375	160. 0	130. 0	....	14. 25	8. 53	304. 25	1. 27	12	8	2. 0
101	299	114. 25	3. 25	160. 0	130. 0	....	14. 25	8. 53	304. 25	1. 20	7	8	2. 0
102	288	115. 0	3. 375	160. 0	130. 0	....	14. 25	8. 53	304. 25	1. 40	34	5	1. 75
104	300	114. 0	3. 25	160. 0	130. 0	....	14. 25	8. 53	304. 25	....	....	....	0. 75

CONDEMNED

14	......	....	......	212. 5	76. 0	....	20. 7	8. 91	309. 2	1. 41	4	2	2. 0
63	......	....	......	160. 0	130. 0	6. 0	14. 25	8. 54	310. 25	1. 30	2	6	......
73	......	....	......	....	301. 0	5. 0	....	9. 0	306. 0	....	3	2	1. 25
103	......	....	......	....	305. 0	....	....	9. 0	305. 0	....	....	......	......

NOTE.—Foundry numbers the same as United States register numbers. The term "hot" is applied to *preponderance, and physical properties of the guns*—Continued.

Casting.	Test of specimens from sinking head.					
Condition of metal when poured.	Apparent specific gravity.	Tenacity of original cross-section.	Ultimate extension per inch.	Reduction in area at fracture.	Tenacity of reduced cross-section.	
		Lbs.	*Inch.*	*P. ct.*	*Lbs.*	
Cool	8. 7978	49, 786	0. 4713	30. 35	71, 476	Head 3 inches short; portion of bronze charge unintentionally left out.
......do	8. 8397	50, 185	0. 4598	39. 83	85, 350	Cooled in furnace.
......do	8. 6062	45, 387	0. 3640	30. 03	64, 869	Do.
Very cool	8. 8464	53, 984	0. 5632	43. 09	94, 860	
......do	8. 8157	50, 185	0. 3410	27. 17	68, 910	
......do	8. 8372	52, 984	0. 5058	47. 08	100, 125	
	8. 5772	44, 387	0. 3154	28. 04	61, 670	

CASTINGS.

	8. 8885	49, 986	0. 3885	38. 56	81, 357	Spoiled in attempting to "burn on" trunnions.
Moderately hot	8. 3903	34, 190	0. 2299	22. 39	44, 055	Condemned for inferior physical qualities.
Very cool	8. 8183	51, 985	0. 3142	20. 60	65, 027	Condemned for large blow-hole near trunnions.
Moderately cool	8. 3626	33, 390	0. 1801	19. 6	41, 534	Condemned for inferior physical qualities.

metal in ebullition, and "very cool" to metal almost sluggish; the remaining terms are intermediate.

For the purpose of discussing the results, and especially in order to establish, if possible, those details in the mode of casting which give good, medium, or bad results, it will be convenient to divide the castings into several classes and observe the average for each. Basing such a division primarily upon the tenacity of the specimen bars and adopting the limits of tenacity given below, we have four classes of those which were accepted and two of the rejected ones, for which the limiting physical qualities of the metal are given in the following table:

TABLE B.—*Physical qualities of castings classified.*

Class.	Tenacity original cross-section, per square inch.	Ultimate extension per inch.	Ultimate reduction in area.	Apparent density.	Hardness.*
	Pounds.	*Inches.*	*Per cent.*		
Class I.—48 guns:					
Maximum	55,584	0. 6846	56. 72	8. 9104	6. 7
Minimum	49, 786	0. 3027	23. 05	8. 6713	5. 15
Mean	52, 494	0. 4884	36. 54	8. 8452	6. 57
Class II.—36 guns:					
Maximum	49, 586	0. 4692	41. 76	8. 9012	5. 33
Minimum	44, 787	0. 2538	19. 16	8. 5851	5. 06
Mean	47, 203	0. 3673	29. 96	8. 7626	5. 18
Class III.—14 guns:					
Maximum	44, 587	0. 4138	37. 77	8. 8134	....
Minimum	40, 588	0. 2500	21. 96	8. 3634	....
Mean	43, 387	0. 3297	29. 02	8. 5974	4. 42
Class IV.—2 guns:					
Maximum	38, 789	0. 2038	19. 72	8. 5888	....
Minimum	36, 987	0. 1846	18. 93	8. 3908	....
Mean	37. 938	0. 1942	19. 325	8. 4898	....
CONDEMNED CASTINGS.					
Class I.—2 guns:					
Maximum	51, 985	0. 3885	38. 56	8. 8885	....
Minimum	49, 986	0. 3142	20. 60	8. 8183	....
Mean	50, 985	0. 3513	29. 58	8. 8534	....
Class II.—2 guns:					
Maximum	34, 190	0. 2290	22. 93	8. 3903	....
Minimum	33, 390	0. 1801	19. 60	8. 3626	....
Mean	33, 790	0. 2050	21. 29	8. 3764	5. 33

* Five specimens only of Class I, 2 of Class II, 1 of Class III, and 1 of Class II, condemned castings were tested for hardness. For the rest, one specimen from each casting is included.

The specimens tested for hardness were taken from the head about 6 inches above the muzzle of the gun proper; their number is, moreover, too limited to enable a general deduction, nevertheless the averages as well as the individual results show that this property increases with the density. The following deductions from Table B are obvious, viz: The greatest ultimate extension, reduction in area, and apparent density are combined with the greatest tenacity. The averages of the several classes show no exception to this rule.

CHARACTERISTICS OF FRACTURE.

Whilst the appearance of the fractured surface of the specimen is characteristic of the class, it is by no means so much so as that of the xterior of the specimen after fracture. The absence of breaks or cross-racks, which leaves the bar smooth to the touch, however much it may e striated or blistered or warped, is invariably an evidence of good uality. As the scale descends, the exterior of the specimen becomes nore and more harsh. The tendency to well-defined striæ or sharp-idged blisters also descends towards lower and broader blisters, which hemselves finally disappear almost, until with the poorest specimens ve find the bar having but little irregularity of outline and covered vith cross-cracks more or less minute.

EFFECT OF VARIATIONS IN THE CASTING OPERATIONS.

Referring to the method of casting before described, and supposing he charges to have been properly proportioned, we revert to the record Table A) for the details followed in the casting of the guns composing the several classes adopted. We are thus led to believe that the quality of the casting is influenced by the following incidents, viz:

1. Interval of time from "copper melted" to "tin added."
2. Interval of time from "tin added" to "crucibles drawn."
3. The aggregate of the two above, and also of the total time the metal is in the furnace, including the time required to melt the copper or copper and bronze.
4. The condition or temperature of the metal when poured.
5. The temperature of the chill.

The following table, showing the *average* times employed in casting and the number of morning and afternoon castings, arranged according to the classes, is given for illustration:

TABLE C.—*Variations in the casting operations.*

Class.	Average time.				Total time from copper melted to crucibles drawn.	Total time from furnace charged to crucibles drawn.	Castings made.	
	Furnace charged to copper melted.	Copper melted to tin added.	Tin added to crucibles drawn.	Crucibles drawn to metal poured.			A. M.	P. M.
	H. M.	*M.*	*M.*	*M.*	*M.*	*H. M.*	*No.*	*No.*
Class I, 48 guns	1 44	11.5	16	4.9	27.5	2 12	12	36
Class II, 36 guns	1 42	9.5	9	5.5	18.5	2 00.5	27	9
Class III, 14 guns	1 29.5	9.5	11	5	20.5	1 50	12	2
Class IV, 2 guns	1 41.5	5.5	4.5	4.5	10	1 51.5	2	0
CONDEMNED CASTINGS.								
Class I, 2 castings	1 41	3	3.5	2	6.5	1 47.5	0	2
Class II, 2 castings	1 30	10	2	6	12	1 42	2	0

This record of averages shows that the charges which were left longest in the furnace gave the best outcome. The relative number of a. m. and p. m. castings in the different classes is significant in several respects. The morning castings were as a rule hurried more than those made after noon; the charged crucibles were put into a furnace not thoroughly heated; the tin was added soon after the copper was melted, and the crucibles themselves soon afterwards withdrawn. The chill, moreover, was not uniformily heated; it was generally hotter outside than inside, and the average temperature varied considerably, probably between 200° and 400° F. On the other hand, for the afternoon castings the metal was charged in hot crucibles; the furnaces were thoroughly heated; the metal was left in the furnace for a considerable time after melting, and the temperature of the chill was uniform and moderate; in all of which contrasts the advantage appears in favor of the latter. The accompaniments of the p. m. castings gave much the best opportunity to regulate the melting heat. In 35 out of 48 of the best castings (p. m.) the interval of time between "copper melted" and "charge withdrawn" averaged between thirty and thirty-five minutes. It may be noted also that in the morning the sand-head was green, whilst in the afternoon it was pretty thoroughly dried, from having been left some time in place upon the heated chill. One would, however, expect the "green" state to be advantageous in retarding the solidification of the head. The only immediate effect observed was that with the green sand-head there was apt to be more or less ebullition from contact of the heated metal with the moist sand.

TEMPERATURE OF THE METAL WHEN POURED.

We need only to refer to Table A to show that for none of the castings belonging to Class I was the metal more than moderately hot when poured, relatively cool and even. Very cool metal gave the strongest material; in fact, the general results showed that it was well to have the metal simply hot enough to flow easily, which is, of course, a matter of experience with the workman. This fact was not left for after elucidation, for it was perceived early in the work, and at once taken advantage of by E. H. Timm, the workman in charge, to whose intelligence and care the good results obtained are mainly due.

The practice of adding a small quantity of planings—from 3 to 8 pounds—to the charge in the crucibles, after skimming and just before pouring, was originally introduced at the forty-eighth casting, and subsequently applied to nineteen others between that and the seventy-fifth casting. The idea was twofold: first, to thicken the metal, which, probably from the use of a quantity of frequently remelted heads, was in some cases unusually fluid; and, second, to reduce the temperature. Of the castings thus treated six came out in Class I, eight in Class II, four in class III, and one in the lowest class of the rejected castings, thus showing no marked deleterious effect. But it was considered at the time that the practice was lowering the general average of the work, and so it was abandoned to give place to that of leaving the metal in the furnace for a time after the melting, with the lid of the furnace partly or wholly removed.

The general practice of keeping the surface of the melted metal well covered with fine charcoal is believed to have had a beneficial influence in preserving uniformity of heat and in retarding oxidation. And similarly that of opening the doors of the foundry as soon as the metal was poured, by which the solidification and cooling of the casting was hastened.*

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* The experiments of Colonel Lavrow, before cited, showed "that it is best to cool the metal rapidly while it is in the liquid state, and to hasten the cooling even after solidification." The chill, however, should not be cooled too rapidly, for Lieutenant Whipple states that "with gun No. 1 the mold was placed during casting in a barrel which was filled with running water. * * * As a consequence the chill cracked. With guns Nos. 2 and 3 water was poured freely on the chill after casting. With Nos. 4 and 5 less water was used, and with No. 6 and following, none was used at all." All the castings named were subsequently rejected, two of them, as stated, "on account of cavities."

THE REJECTED CASTINGS.

There were four of these, two, Nos. 14 and 73, having metal of high tenacity, and two, Nos. 63 and 103, with metal of inferior tenacity.

No. 14, tenacity 49,986 pounds per square inch, was a good casting, except for some small cavities in the trunnions; it was subsequently spoiled in the second attempt to burn on new trunnions.

No. 73, tenacity 51,985 pounds per square inch. This casting was made entirely of "lower heads," that is to say, of portions of the sinking heads within 6 inches above the muzzle of the gun proper. No ingot metals were put in the charge. The metal was poured very cool, possibly too cool. When the skin of the casting was turned off in the lathe it was found to contain numerous small cavities, and one about 0.2 of an inch in diameter, extending to the position of the bore through the second reinforce, that is, just below one trunnion in the casting position.

No. 63, tenacity 34,190 pounds per square inch. The charge was a usual one, and the metal was poured "moderately hot"; both crucibles, however, were cooled by adding planings after skimming, thus departing from the usual practice in such case of adding to but one of the crucibles and reserving hot metal for the sinking head. The casting did not shrink, but, if anything, expanded slightly on cooling.

No. 103, tenacity 33,390 pounds per square inch. Like No. 73, this casting was made entirely of lower heads. The chill had been out of use for some days, and was probably a little rusted. The casting pit was closed at the time, and the chill was lowered into the furnace pit (in front of the fire) for convenience in pouring. The casting did not shrink on cooling.

The results from Nos. 73 and 103 point to the necessity of using a certain portion of ingot metal for each charge, and again from No. 103 to the ill effect of heated surroundings for the chill after the pouring is complete.

CONCLUSIONS.

For casting bronze guns of the dimensions and with the appliances herein described, we may note the following as tending to produce the best qualities of metal:

1. The ingot metals used should be of the best quality, and the charge should contain about 9 per cent. of tin, the metals being weighed with care.
2. The charge should always contain a portion of new metals.*
3. The furnace should be thoroughly heated before the crucibles are introduced, and it would be well also to heat the crucibles themselves before charging the copper or copper and bronze.
4. The fire should be well kept up, and urged especially about the time of melting copper, and the surface of the metal covered with charcoal after the melting begins.
5. The metal should remain in the furnace from 30 to 40 minutes, after the copper is melted, before withdrawal; during which time the temperature of the furnace may be lowered a little before the tin is introduced, and should be rapidly lowered afterwards.

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* In the present case, except for three castings, which were made entirely of old bronze (lower heads), and of which two were failures, the charge containing the least proportion of new metals but one which was largely used, was as follows: Ingot copper, 160 pounds; heads, 130 pounds; ingot tin, 14.25 pounds.

6. The ingot tin should be broken in small pieces and put directly into the crucible from 25 to 30 minutes after the copper is melted, the contents of the crucible thoroughly mixed by stirring, and a fresh dressing of charcoal added.*

7. After withdrawal from the furnace the contents should be again thoroughly stirred before the crucibles are skimmed. The best condition of the metal at this stage is believed to be a medium temperature (rather cool than hot), but sufficient to allow it to run easily, and a fair consistency.

8. The chill should be moderately and uniformly heated; that is, it should be thoroughly warmed throughout.

9. The metal should be poured as soon as possible after skimming, directly from the crucibles into the runner box, taking care to keep the latter well filled, and in case one crucible is hotter than the other, reserving the principal part of its contents for the last.

10. The runner-box should be at once removed, the top of the casting covered with some non-conducting substance (charcoal probably being best on account of cleanliness), and the chill exposed to cooling currents of air. A rapid shrinkage of the head is indicative of a good casting; in cases it is almost immediate with a motion perceptible to the eye.

11. The interior of the chill should be kept perfectly clean and free from rust, &c.; when cracks appear they should be hammered close and the chill prepared for use by coating with a wash of black lead to prevent scaling of the iron.

MECHANICAL TESTS MADE WITH THE UNITED STATES TESTING MACHINE AT WATERTOWN ARSENAL, MASS.

In order to obtain more complete tests of the metal than could be made with the machine at this foundry, duplicate test pieces were taken side by side with the regular ones from the sinking head of ten of the castings. Tests of these duplicates were made with the United States testing machine at Watertown Arsenal, and the results furnished by Maj. F. H. Parker, United States Ordnance, commanding the arsenal, are appended. These tests supply a knowledge of the elastic properties and extensibility of the metal under varying loads. Besides the determination of these qualities, they differ from those made at the foundry in that the stress was applied intermittingly, being removed after the addition of each regular increment of 1,000 pounds per square inch, whilst in the tests made here the stress was continuously applied until the specimen broke, except that each specimen had to be removed once to reset the machine, which did not afford sufficient scope for the stretch of the specimen at the first setting. The Watertown specimens were also one and four-tenths inches greater in length between gauge-marks.

The following table gives a summary of the results of the Watertown tests, to which is added a column giving the mean results of the duplicate tests (ten specimens) made at this foundry for comparison:

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* In these castings this interval of time was frequently inversely divided, and gave good results; that is to say, the tin was added shortly after the copper was melted, and the longer interval placed between this time and the withdrawal.

TABLE D.—*Summary records of tests of metal from ten bronze gun castings (contract of December 14, 1883) made at Watertown Arsenal, Massachusetts.*

Mark on specimen (casting number).	27	33	47	49	63[1]	71
Estimated to contain:						
Copper	91.17	91.19	91.47	91.39	91.46	91.46
Tin[2]	8.83	8.81	8.53	8.61	8.54	8.54
Apparent density	8.5916	8.8834	8.6322	8.8949	8.3696	8.9852[3]
Hardness	5.27	6.13	5.38	7.16	4.78	6.71
SPECIMEN.						
Length between shoulders	3″.0	4″.5	4″.5	4″.5	4″.5	4″.5
Gauged length	3″.0	4″.0	4″.0	4″.0	4″.0	4″.0
Diameter of original cross-section	0″.564	0″.798	0″.798	0″.798	0″.798	0″.798
Area of original cross-section, square inches	0″.25	0″.5	0″.5	0″.5	0″.5	[illegible].5
Elastic limit	12.000	15.000	13.000	14.000	9.000	[illegible].000
Extension per inch at elastic limit	0.000967	0.000725	0.000775	0.000675	0.00055	0.000775
Ultimate resistance per square inch of original area	43.520	52.100	44.700	51.160	35.900	47.800
Ultimate extension per inch	0″.28	0″.512	0″.32	0″.46	0″.217	0″.33
Contraction in area at fracture	28.0	44.0	....	42.0	20.0	34.0
Module of elasticity[4]	12,875,000	20,000,000	16,000,000	20,200,000	....	19,200,000

Mark on specimen (casting number).	73[5]	95	97	99	Mean results Watertown Arsenal.	Mean results West Point foundry.
Estimated to contain:						
Copper	91.0	91.47	91.47	91.47	....	....
Tin[2]	9.0	8.53	8.53	8.53	....	....
Apparent density	8.8359	8.7650	8.8212	8.6247	8.7404	8.705
Hardness	7.40	5.32	6.07	5.12	5.934	5.9[6]
SPECIMEN.						
Length between shoulders	4″.5	4″.5	4″.5	4″.5	4.5	3.0
Gauged length	4″.0	4″.0	4″.0	4″.0	4.0	2.6
Diameter of original cross-section	0″.798	0″.798	0″.798	0″.798	0.798	0.798
Area of original cross-section, square inches	0″.5	0″.5	0″.5	0″.5	0.5	0.5
Elastic limit	10.000	11.000	13,000	14.000	12.250	....
Extension per inch at elastic limit	0.0006	0.000625	0.0007	0.008	0.000719	....
Ultimate resistance per square inch of original area	51.400	43.680	50.980	44.100	46.534	47.005
Ultimate extension per inch	0″.357	0″.277	0″.51	0″.33	0.359	0.361
Contraction in area at fracture	32.0	30.0	40.0	34.0	33.8	27.8
Module of elasticity[4]	....	17,600,000	18,570,000	19,200,000	....	....

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[1] Condemned for inferior tenacity of metal.

[2] The proportion of tin is possibly a little underestimated; the actual mean, however, probably does not exceed 9 per cent.

[3] This appears to be an error; the density of this metal, as taken at West Point foundry, was 8.8236.

[4] Most probable values, computed from extensions within the elastic limit.

[5] Condemned for unsound casting.

[6] From tests made by Lieut. C. W. Whipple, U. S. Ordnance, at Sandy Hook, N. J.

NOTE.—All specimens were taken from gun-head next to muzzle of piece, as near outside as possible and parallel to axis.

These results show that the difference in ultimate resistance of specimens of bronze tested intermittingly and continuously is not great, and similarly for the ultimate elongation per inch. But the reduction in area at point of fracture for the former is considerably greater, indicating that the intermittent application of the stress caused the specimen to stretch most about the point of fracture, or at least that the stretch of the stem was less evenly distributed than under the continuous stress.

The difference in densities determined may be partly accounted for in that the half specimens which had been broken at this foundry were used at Watertown for a redetermination of this property, whilst at this place the whole specimen was weighed before subjection to the tensile test.

Omitting Nos. 63 and 73, which were taken from rejected castings, we find the following in the results of the Watertown tests:

Tenacity:		
Maximum per square inch	pounds..	52,100
Minimum per square inch	do....	43,520
Elastic limit:		
Maximum per square inch	do....	15,000
Minimum per square inch	do....	11,000
Elongation at elastic limit:		
Maximum thousandths of the linear unit		0.967
Minimum thousandths of the linear unit		0.625
Module of elasticity:		
Maximum per square inch	pounds..	20,000,000
Minimum per square inch	do....	12,875 530

Compared for tenacity the results show generally that the tenacity of the weaker specimens under the West Point Foundry test was increased at Watertown, whilst for the strongest specimens the reverse took place.

THE PROJECTILES.

The projectile consists of a solid cast-iron cylindrical body with an ogival head, described with a radius of one caliber and a base formed of the frustum of a cone; a wrought-iron shank is screwed into the base, having an eye at its rear extremity for attaching the shot-line.* The form and dimensions are shown in Figs. 1, 2, and 3, Plate IV.

The principal parts are as follows:

Total length of body	inches..	15.7
Length of ogival head	do....	2.17
Radius of head	do....	2.50
Length of cylindrical part	do ...	12.43
Diameter of cylindrical part	do....	2.5
Length of frustum	do....	1.1
Diameter of smaller base of frustum	do....	1.35
Shank:		
Total length	do....	6.50
Length of screw	do....	1.50
Diameter of screw	do....	1.0
Length from plane of base	do....	5.0
Distance from base to center of eye-hole	do....	4.5
Diameter of eye-hole	do....	0.4
Width at eye	do..	1.0

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*See report on life-saving apparatus, p. 206, by Lieut. D. A. Lyle, Ordnance Department, U. S. Army.

Shank—Continued.

Thickness through eye	inches	0.4
Thickness around eye	do	0.3
Diameter of neck	do	0.625
Distance of center of gravity from plane of base	do	7.45
Weight (average)	pounds	18.75

The projectiles are cast head down with a sinking head from 5 to 6 inches in length above the base. The pattern for the sand mold is a simple cylinder of wood about 0.2 inches larger in diameter than the finished projectile, and having a head corresponding in form to that of the projectile. A number of projectiles may be cast in each flask, depending upon the size of the latter. As a rule, four projectiles were cast in each flask in the present instance. The usual form of flask was used. The molds for the projectiles being arranged in the lower portion with a single runner through the middle of the upper portion, branching at the junction of the flask into four channels leading into the top of the molds. No risers were used. The molds were oven-dried. A mixture of iron, averaging about 10 per cent. of Shaparoon No. 2, and 45 per cent. each of air-furnace scrap and Hudson No. 2, was used in charging the air-furnace from which all the castings were made.

At this foundry the cylindrical part of the projectile is finished by circular cutters, through which the projectile is forced by hydraulic pressure, as described in the Report of the Chief of Ordnance for 1880, page 212. The sinking head is first cut off, the shank hole drilled, and the base of the cylinder prepared for the press. Following the operations in the press, the head, frustum, &c., are finished in the lathe.

The shanks are forged in suitable dies. They are then mounted in the lathe and tool-finished for threading, whilst the shank portion is simply filed. The thread is afterwards cut with a die. The exterior of the eye portion is finished by hand-filing and the eye proper drilled and shaped in the drilling machine.

A tenacity specimen of the usual form for cast iron is taken from at least one shot of each lot cast, generally from the lower portion of the sinking-head. The tenacity should not be less than 25,000 pounds per square inch. The 1,200 projectiles accepted under the present contract were cast in eight lots, varying in number from 52 to 268. The tenacity of the 8 specimens ranged from 24,624 to 28,640 pounds per square inch, with an average of 26,250 pounds, and the density from 7.1794 to 7.2602, with an average of 7.2258. "The projectiles when finished must have no flaws or seams that would scratch or injure the bore [of the gun] and must weigh between 18.5 and 19 pounds."

The inspecting implements necessary for gauging the assembled projectile are shown in Figs. 4 and 5, Plate IV. They are—

1. The *profile for projectile* (Fig. 5), which is made of steel and carefully finished, to gauge the lengths, shape of the head, cylindrical part, and frustum of the projectile.
2. The *shank gauge* (Fig. 4), which is made of steel. It is arranged to gauge the different parts of the shank, viz, length from plane of base, distance from base to center of eye-hole, diameter of eye-hole, thickness through eye, and diameter of neck, giving the maximum and minimum measurements allowed for each.

The final but most important gauge of the projectile is that it must fit "air-tight" in a gun of which the bore is exactly 2.5 inches diameter. Although all the guns were gauged to be air-tight with the cylinder gauge provided for the bore, yet it was of course impracticable to bore

100 guns precisely alike, and in some the gauge did fit more closely than in others. To gauge the shot, therefore, two guns were selected which were considered, from the action of the gauge, to have, respectively, the smallest and largest bores in the lot. The greater number of the projectiles were tried in the smaller, since it was found that although none were too small for the larger, yet several which entered this gun readily would not enter the other. All such projectiles were laid aside to be reworked and subsequenty tried in the smaller bore.

CONTRACT OF MAY 14, 1884, FOR 35 GUNS AND 420 PROJECTILES.

(Service numbers of guns from 301 to 335, inclusive.)

This contract—the second within the fiscal year—was made to supply guns and projectiles of the life-saving pattern (Lyle model, 1877) for the use of the Revenue Marine Service.

Following close upon the completion of the previous contract, the same method of manufacture was pursued, with some slight variations, which will be noted. One of these guns was, however, fired a number of rounds for extreme proof, first with service charges, and then with charges (of powder) increasing in amount until the final twenty rounds, which contained double the service charge. The facts developed by this extreme proof are considered important and will be discussed in detail.

In the previous contract the proportion of tin was fixed between 8 and 10 per cent. In the present case the lower limit was raised and the amount of tin to be used fixed between 9 and 10 per cent. In both cases, however, the charges of metal actually used were made to approximate a proportion of 9 parts of tin in 100.

The same ingot metals were continued in use as before, viz, Lake Superior copper (Quincy Mining Company) and Banca tin. Up to casting No. 18, inclusive, the charges of metal contained a relatively high percentage of ingot copper, and differed in no essential respect from those previously described. Beginning with casting No. 19, however, and following, the proportion of ingot copper was reduced to about 17 per cent. of the charge without, as will be seen, causing any apparent deterioration in the quality of the castings. With these latter one of the two crucibles required for each casting was charged with old bronze alone, the other partly with bronze and partly with new metals, and to this crucible the whole of the ingot tin was added. But the usual care was taken with both crucibles to keep the top covered with charcoal while in the furnace, and to thoroughly mix the contents by stirring. In some cases the contents of the two crucibles were mixed by pouring after being taken from the furnaces, using a third crucible (heated) for this purpose, but this practice was not continued.

The old chills, although badly cracked inside and for this reason requiring greater care and much labor in calking, were continued in use. With castings Nos. 1 and 2 (the latter of which was afterwards condemned) a pattern was used for molding the sand-head, which had become worn at the bottom by contact with the heated chill and thus caused a shoulder to be formed in the mold at the base of the sand-head. The injurious effect of this was at once apparent in the castings, both of which were cracked around the chase just below the sand-head, the shoulder having acted to prevent the metal in the sand-head from sinking properly to supply the shrinkage below. A new pattern was at once substituted.

All of the guns were subjected to the usual proof-firing and to the inspection before described.

The following table gives a record of the castings, the numbers, weight, and breech preponderance of the finished guns, and the physical qualities of their metal:

TABLE E.—*Record of casting, register number, weight,*

Order of castings.	Finished gun.			Casting.									
				Metals used.						Time.			
					Bronze.								
	United States register number.	Weight.	Breech preponderance.	Ingot copper.	Heads.	Turnings, borings, and planings.	Ingot tin.	Percentage of tin.	Total weight.	Furnace charged to copper molted.	Tin added to metal taken from furnace.	Metal drawn to casting.	Shrinkage of upper surface in mold.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Pr. ct.*	*Lbs.*	*H. M.*	*M.*	*M.*	*Inch.*
1	301	109.25	3.125	180.0	110.0	....	17.0	8.76	307.0	1.50	17	5	......
3	303	111.0	3.25	180.0	110.0	....	17.0	8.76	307.0	1.55	10	4	0.5
4	304	114.25	3.375	180.0	110.0	....	17.0	8.76	307.0	2.30	5	7	1.75
5	305	113.5	3.25	180.0	110.0	....	17.0	8.76	307.0	1.45	19	8	1.625
6	306	112.75	3.25	197.0	96.0	....	18.0	8.53	311.0	1.55	10	4	1.5
7	307	114.0	3.25	197.0	98.0	....	18.0	8.57	313.0	1.55	10	4	1.25
8	308	115.0	3.125	180.0	110.0	....	17.0	8.76	307.0	2.30	5	7	3.0
9	309	112.75	3.625	144.0	145.0	....	12.5	8.47	302.5	1.45	12	10	1.0
11	311	111.75	2.875	112.0	186.0	....	10.25	8.75	308.25	1.50	11	7	1.25
12	312	114.0	3.625	112.0	186.0	....	10.25	8.75	308.25	2.35	5	5	0.5
13	313	114.5	3.375	174.0	116.0	....	16.0	8.64	306.0	2.10	26	4	2.5
14	314	113.25	3.25	180.0	110.0	....	17.0	8.76	307.0	1.55	7	4	1.25
15	315	114.5	3.125	90.0	213.0	....	7.0	8.44	310.0	1.45	20	4	2.375
16	316	112.75	3.0	170.0	120.0	....	15.5	8.60	305.5	1.40	27	5	1.5
17	317	112.0	3.25	90.0	112.0	102.0	8.125	8.80	312.125	2.13	28	5	1.5
18	318	112.0	3.375	103.0	122.0	75.0	9.25	8.70	309.25	2.14	33	6	1.25
19	319	114.0	3.0	53.0	129.0	118.0	4.75	8.85	304.75	2.53	26	5	1.75
20	320	114.75	3.125	53.0	125.0	122.0	4.75	8.85	304.75	1.55	12	5	1.5
21	321	113.0	3.0	53.0	126.0	124.0	4.75	8.85	307.75	1.50	21	5	1.5
23	323	115.25	3.125	53.0	130.0	120.0	4.75	8.85	307.75	0.50	33	5	1.5
24	324	115.0	3.125	53.0	114.0	136.0	4.75	8.85	307.75	0.50	36	5	2.0
25	325	113.75	3.25	53.0	125.0	125.0	5.25	9.0	308.25	2.0	32	2	1.75
26	326	113.5	3.125	53.0	125.0	125.0	5.25	9.0	308.25	2.0	21	4	1.5
27	327	115.0	3.125	53.0	120.0	130.0	5.25	9.0	308.25	2.0	27	3	2.0
28	328	114.75	3.125	53.0	108.0	142.0	5.25	9.0	308.25	1.15	45	5	2.0
29	329	113.5	3.125	53.0	129.0	121.0	5.25	9.0	308.25	1.50	25	5	1.75
30	330	113.0	3.125	53.0	129.0	121.0	5.25	9.0	308.25	2.13	19	5	1.75
31	331	114.5	3.0	36.0	155.0	101.0	3.5	8.98	295.5	1.25	49	4	1.5
32	332	114.0	3.25	33.0	148.0	121.0	3.25	8.99	305.25	1.0	24	2	2.0
33	333	113.25	3.125	53.0	125.0	125.0	5.25	9.0	308.25	2.0	33	3	1.25
34	334	113.0	3.25	53.0	125.0	125.0	5.25	9.0	308.25	2.0	25	5	1.5
35	335	114.75	3.25	53.0	228.0	22.0	5.25	9.0	308.25	2.10	15	4	1.0
36	302	112.25	3.375	53.0	120.0	122.0	5.25	9.0	300.25	1.20	43	3	1.75
37	310	113.25	3.125	90.0	210.0	....	10.0	9.32	310.0	1.40	22	3	1.125
38	322	114.0	3.0	90.0	210.0	....	11.125	9.65	311.125	2.05	39	4	1.5

USED FOR EX

10	......	....	......	144.0	146.0	....	12.5	8.47	302.5	2.0	15	7	0.5

CONDEMNED

2	......	....	......	180.0	110.0	....	17.0	8.76	307.0	2.0	17	4	......
22	......	....	......	53.0	124.0	126.0	4.75	8.85	307.75	2.02	26	6	1.5

breech preponderance, and physical properties of the guns.

Condition of metal when poured.	Test of specimens from sinking-head.					Remarks.
	Apparent specific gravity.	Tenacity of original cross-section.	Ultimate extension per inch.	Reduction in area at fracture.	Tenacity of reduced cross-section.	
		Lbs.		*Pr. ct.*	*Lbs.*	
Medium temperature	8. 4680	42, 988	0. 308	30. 77	62, 100	Cracks around casting at base of sand-head. Chill cool.
......do	8. 3194	41, 188	0. 4115	35. 78	64, 100	
......do	8. 7749	47, 386	0. 427	41. 38	80, 800	Taken hot from furnace and cooled in air uncovered.
......do	8. 7400	46, 387	0. 3731	36. 88	73, 500	Do.
......do	8. 6334	43, 987	0. 3435	32. 53	64, 800	One crucible contained bronze only mixed with other before casting.
......do	8. 7686	43, 388	0. 377	30. 35	62, 300	Do.
......do	8. 8643	52, 984	0. 5212	44. 41	95, 300	Chill quite warm.
......do	8. 6588	44, 690	0. 354	34. 36	62, 500	
One crucible hot and liquid; one crucible medium temperature	8. 8201	51, 785	0. 55	45. 80	95, 500	The hot crucible contained gun No. 73 (old number) entire.
Medium temperature.	8. 4798	42, 787	0. 3231	25. 45	57, 400	Shrunk rapidly 1.25 inches; then rose 0.75 inches five minutes later.
......do	8. 8181	51, 585	0. 4384	28. 45	72, 100	Casting completely set in four minutes.
......do	8. 6351	41, 988	0. 3384	31. 18	61, 000	
......do	8. 8474	49, 586	0. 378	20. 30	......	Charge too great; mold overflowed.
......do	8. 7386	43, 388	0. 4	34. 87	66, 600	Rapid shrinkage; casting set in three minutes.
......do	8. 5969	41, 787	0. 2731	25. 89	56, 400	Shrinkage to one inch very rapid.
......do	8. 5702	42, 588	0. 3	25. 89	57, 450	Taken hot from furnace and cooled in air uncovered.
......do	8. 6204	48, 386	0 4538	36. 58	76, 300	Reduced charge copper (continued below).
......do	8. 8289	50, 984	0. 4808	40. 90	103, 700	
......do	8. 6345	43, 987	0. 308	20. 39	55, 250	Casting rose slightly in center after first shrinkage.
Hot and liquid	8. 8508	48, 985	0. 45	41. 47	83, 700	Chill rather cool.
One crucible hot; one crucible quite cool.	8. 8682	49, 774	0. 4538	40. 80	84, 100	Some metal in cool crucible set in pouring.
Cool	8. 8538	46, 186	0. 3731	27. 60	63, 790	Some metal in one crucible set in pouring.
Moderately cool	8. 7264	45, 986	0. 3692	30. 66	66, 300	
Cool	8. 8408	51, 985	0. 4731	35. 15	80, 070	Some metal in one crucible set in pouring.
Medium temperature	8. 8451	51, 085	0. 5077	43. 66	90, 490	
Hot	8. 7117	45, 396	0. 3307	32. 94	67, 675	Temperature of melting high, partly lowered by removing furnace covers.
Medium temperature.	8. 6676	44, 888	0. 354	20. 72	63, 150	
......do	8. 8292	49, 386	0. 4307	30. 76	71, 330	Charge contained one-half of condemned casting No. 22 below.
Cool	8. 7206	44, 388	0. 3231	31. 73	70, 210	Do.
Medium temperature.	8. 7068	45, 482	0. 3384	20. 09	64, 285	
One crucible hot; one crucible cool.	8. 7004	45, 187	0. 308	28. 98	63, 625	Casting rose slightly after first shrinkage.
Medium temperature.	8. 8104	47, 385	0. 2769	20. 28	50, 440	Do.
Cool	8. 6203	42, 387	0. 2846	26. 96	58, 030	Head two inches short, from small charge.
......do	8. 7072	45, 786	0. 2731	21. 95	58, 665	Per cent. of tin in charge increased.
Medium temperature.	8. 7962	46, 786	0. 2884	27. 82	61, 420	Same as above. Slight rise in center after first shrinkage.

TREME PROOF.

Medium temperature.	8. 3904	40, 188	0. 2923	26. 32	54, 500	Selected because of low physical properties.

CASTINGS.

Cool	8. 3185	38, 988	0. 2615	25. 24	52, 200	Condemned for inferior density and low physical properties.
......do	......	......	......	......	......	Condemned as soon as cast for cavities in chase.

The fracture of the tensile-test specimens, taken as before from the outside of the sinking-head just above the muzzle of the gun proper. exhibited characteristics similar in all respects to those previously described, The column of "Tenacity of original cross-section" in table shows that: 6 specimens gave tenacities above 50,000 pounds per square inch; 15 between 45,000 and 50,000; and 14 between 40,000 and 45,000, none being below a tenacity of 40,000 pounds per square inch. This record, whilst good in itself, is below that of the previous contract, giving an average tenacity of about 46,350 for 35 guns against about 49,000 for 100 guns. This deterioration is believed to be due to the use in the charges of old bronze which had been several times remelted and had lost relatively a greater proportion of its tin than its copper, the lowering of the percentage of tin thus giving a loss of tenacity.

HARDNESS.

Castings No. 26 to 38 inclusive were tested for hardness, the test discs being taken from the outside immediately above the muzzle of the gun proper and thus from the lower end of the tensile-test piece in position instead of from the upper end as in the previous contract. The tests were made by Lieut. C. W. Whipple, U. S. Ordnance, upon the testing machine at Sandy Hook, and gave the following results:

TABLE F.—*Hardness of bronze, 2¼-inch Lyle life-saving guns.*

No. of specimen.	Length of cut.	Hardness.	Remarks.
	Inches.		
26	0. 905	4. 50	Hardness of copper = 3. 33.
27	0. 865	5. 15	Pressure applied, 10,000 pounds.
28	0. 870	5. 06	
29	0. 895	4. 65	
30	0. 900	4. 57	
31	0. 870	5. 06	
32	0. 895	4. 65	
33	0. 895	4. 65	
34	0. 900	4. 57	
35	0. 875	4. 98	
36	0. 915	4. 35	
37	0. 895	4. 65	
38	0. 860	5. 24	

For the two last castings an increased charge of tin was used, amounting in No. 37 to 10 per cent., and in No. 38 to 11 per cent., of the charge of *new* metals. This increase of tin was intended, in No. 38 at least, to bring the percentage of tin fully up to that used in any casting made under the two contracts.[*] But in the absence of accurate data as to

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[*] Remarks on castings Nos. 37 and 38. Previous castings having shown a tendency to undue softness, which was believed due to loss of tin from frequent remeltings of heads, the charge of tin for No. 38 was computed as follows (on a basis of 9 per cent. for the charge), viz: New copper, 90 pounds, demanded 9 pounds of tin. It was further assumed that the heads had been remelted three times. The loss of weight in casting, previously determined, was eight-tenths of 1 per cent. of the whole for each casting. Crediting five parts of this loss to the copper and two parts to the tin ("two to three parts of copper are lost to one of tin"), the loss of tin for each melting was twenty-three hundredths of 1 per cent., and for four meltings then about 1 per cent., thus leaving the heads with about 8 per cent. of tin, and giving the following basis for the charge:

	Copper.	Tin.
	Pounds.	*Pounds.*
New metals	90. 0	9. 0
210 pounds bronze, containing 8 per cent. tin	193. 2	16. 8
Added to make whole charge contain 9 per cent. tin	....	2. 125
Total	283. 2	27. 925

With No. 37 only 1 pound of tin was added, for experiment.

the amount of tin lost from the heads of these castings at each melting, the intention of the increase was mainly experimental.

The tensile tests from these two castings do now show equal to some of the previous ones, but that of No. 38, containing the greater proportion of tin, gave the higher tenacity. The working of the metal under the lathe tool, and subsequent firing proof of these two castings, showed them to be of excellent quality. But their increase in hardness is not marked as compared with the average of previous castings, under this contract, nor even in No. 38 is it equal to the average hardness given by the tests under previous contract. From which it might be inferred that the proportion of tin was still small. But considering that the average hardness of eight accepted castings, under previous contract, was 5.89, and of thirteen, under this contract, was 4.78, we are led to believe that the difference in position of the test pieces effected the results for hardness, and that since the first named were taken from the sinking head about 6 inches higher than the last, we may conclude that the upper portions of the sinking heads do contain more tin than the lower, for it is generally accepted that the hardness of bronze increases with the proportion of tin. This opinion as to the effect of position of specimen on hardness is confirmed by the individual tests; they are nearly uniform for the last contract, but irregular, and some of them abnormally high for the previous contract (see Table D). One conclusion to be drawn from this is opposed to the opinion before expressed (see foot-note, page 373) that' there is very little segregation of tin towards the head in these comparatively small chill castings. These tests for hardness show rather that the tin does rise into the head, but in unequal quantities.

Chemical analysis should undoubtedly go hand in hand with the casting of these guns, or at least until the law of supply of tin in the sinking heads as affected by each melting or remelting is well determined. But in the absence of that we may from the foregoing limited observations draw the following rule for practice: In using old bronze (sinking heads, &c.) for new charges, assume that for each melting the loss of tin is given by one-fourth of 1 per cent. of the original ingredient of that metal contained in the charge; that is, if the original charge contained 9 per cent. of tin after one melting, the sinking head will contain 8.75 per cent. nearly. It is not improbable, however, that the continued application of this rule would eventually introduce too large a proportion of tin, and the rule stands to be modified by future experience.

The hardness of these thirteen test pieces, compared with the densities determined from contiguous pieces from the same castings, show, with scarcely an exception, that this property of bronze increases with the density, and confirms the results before obtained (see Table D.)

THE FIRING PROOF.

Each gun was subjected to the three proof rounds prescribed, "8 ounces Hazard navy cannon powder and a projectile weighing not less than 18 pounds," with the trunnions in a finished condition, the exterior diameters about 0.04 inch over finished size and the bore about 0.05 inch under the finished size. The carriage (see page 375) used for the proof of these guns weighed 96 pounds, about 40 pounds more than the weight of the carriage used in service, and was roughly constructed. Owing to slight variations in the diameter of the bores in their unfinished state, the proof projectiles did not fit all of them air-tight; in some cases the play amounted to 0.02 inch, in others there was an air-tight fit, whilst the remainder were intermediate. Under these circumstances it was found upon inspection after the proof that none of the guns had suffered any appreciable enlargement of the bore, but that the trunnions of many of them were slightly bent forward, the maximum bending being found in casting No. 10, where it amounted to 0.019 inch, measured at the outer end of the trunnions from the face of a square resting on the plane of the rimbase against the base of the trunnion. For the remaining guns this bending was limited to about 0.01 inch or less. The apparent bending, as measured, was intensified by the fact that the rear of the trunnions was slightly compressed in recoiling against the cap squares and left a corresponding shoulder at the base of the trunnion against which the square abutted in taking the measurements. Upon the whole these guns, although fulfilling the requirements established by the Department to govern their acceptance, based upon "the tensile strength and other physical qualities of the bronze employed and in quality of workmanship and finish," were considered scarcely equal to those made under the previous contract. Accordingly that one of the whole lot, casting No. 10,* which exhibited the lowest general average of physical qualities was selected for extreme proof.

THE EXTREME PROOF.

After being subjected to the usual proof firing of three rounds, the gun was entirely finished and the firing was commenced with the service charge of 8 ounces of powder and a projectile weighing 18.5 pounds, which fitted the bore air-tight. The carriage used for the ordinary proof of the guns was changed to conform more nearly to service conditions. It was reduced in weight to 60 pounds, and the cap squares (or seats for the steel rings used over the trunnions) were made "true" in a lathe. By means of a specially constructed caliper (the bore being too small to use the star gauge), fairly accurate measurements of the successive enlargements of the bore were obtained; measurements were also made of the exterior at the diameters of maximum enlargement for the chase and first reinforce (breech); of the distance between the rimbases, and of the bending of the trunnions.

The record of the extreme proof firing is given in the following table:

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*Casting No. 2 stood below this in the list. Its test gave a tenacity of about 39,000 pounds per square inch or 3,000 more than prescribed; but its density was very low and the deformation of its trunnions under the firing proof was marked. It was therefore condemned, against the representations of the contractors, for "inferior density and low physical properties."

TABLE G.—*Extreme proof of gun—casting No. 10.*

FIRST PROOF.

Total rounds.	Charge.					Bore.								Exterior dimensions.						
	Number of rounds.	Powder.		Projectile.		At muzzle.		6 inches from muzzle.		11 inches from muzzle.		17 inches from muzzle.		Chase.		First reinforce.		Trunnions bent forward.	Rim bases.	
														4 inches from muzzle.		3 inches forward of vent.				
		Kind.	Weight.	Kind.	Weight.	Diameter.	Successive enlargement.	Diameter.	Successive enlargement.	Diameter.	Successive enlargement.	Diameter.	Successive enlargement.	Diameter.	Successive enlargement.	Diameter.	Successive enlargement.		Distance between.	Successive enlargement.
			Ozs.		*Lbs.*	*Inch.*	*Inch.*	*Inch*	*Inch.*	*Inch.*	*Inch*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
8	3	Hazard navy cannon	8	Solid cast-iron cylinder	18 0	2.45	.0	2.45	.0	2.45	.0	2.45	.0	4.545	.0	5.545	0.	0.019	5.7	.0
								EXTREME PROOF.												
6	3	Hazard navy cannon.	8	Solid cast-iron cylinder.	18.5	2.5	0.003	2.5	.0	2.5	.0	2.5	0.1	4.505	0.034	5.505	0.045	0.021	5.7	.0
13	7		8		18.5	2.503	.0	......	......	......	......	2.6	.0	4.530	.0	5.55	.0	0.021	......	......
23	10		8		18.5	......	....	......	......	......	......	2.6	0.003	4.530	0.001	5.55	.0	0.0225	......	......
53	30		8		18.5	2.503	0.017	......	0.055	......	0.047	2.603	0.01	4.54	.0	5.55	.0	0.0225	......	0.02
103	50		8		18.5	2.52	0.004	2.555	0.002	2.547	.0	2.613	.0	4.54	.0	5.55	.0	0.0225	......	......
113	10		10		18.5	2.528	0.003	2.557	......	......	......	2.613	0.007	4.54	.0	5.55	.0	0.036	5.72	.0
123	10		12		18.5	2.531	0.012	......	......	......	......	2.62	0.05	4.54	0.02	5.55	0.03	0.0475	......	......
143	20		14		18.5	2.543	0.024	......	......	......	......	2.67	0.022	4.56	0.02	5.58	0.03	0.0575	......	......
163	20		16		18.5	2.567	0.083	......	0.153	......	0.169	2.692	0.068	4.58	0.035	5.61	0.13	0.0775	......	0.07
Final measurements with total enlargements					......	2.65	0.15	2.71	0.21	2.716	0.216	2.76	0.26	4.615	0.11	5.74	0.235	0.0775	5.79	0.09

The total enlargement of the bore and exterior at the end of the 100 rounds fired with the service charge are shown in Plate V. The profile of the bore is a sinuous line, showing two places of maximum enlargement, one about 2 inches in front of the vent and within the first reinforce, the other within the chase, about 6 inches from the muzzle, the additional strength afforded by the rim bases giving a contracted portion of the bore within them. The exterior of the gun shows the same results. The trunnions behaved remarkably well. After the 100 service rounds were fired the total "set" was 0.0225 inch, or but 0.0035 inch more than at the commencement of the extreme proof, and at the conclusion of the extreme proof the total forward bending was less than 0.1 inch, whilst there was no evidence of rupture. The vent piece was broken short off at the exterior of the gun at the 19th round by striking against a piece of iron lying in the sand where the gun recoiled.

At the conclusion of the proof the gun was cut in two through the first reinforce for an examination of the bore and vent piece. Other than the enlargement of the metal of the bore it gave no evidence of rupture. It was considerably scored, probably due in part to the repeated use of proof projectiles taken from the sand-butt and the sanding of the gun when it recoiled (although the bore and projectiles were wiped), but otherwise it appeared sound, and proved that under no conditions of service could a dangerous bursting of the gun be anticipated. Further than this, the extreme proof showed that no danger need be apprehended in a continued use of these guns in service, even after excessive enlargements of the bore and exterior, for this relatively inferior gun remained in safe condition, as regards bursting, when the bore was enlarged from 2.5 to 2.76 inches, an increase of one-quarter of an inch, the first reinforce from 5.5 to 5.74 inches, and the chase, at 4 inches from muzzle, from 4.5 to 4.615 inches. How far this enlargement of the bore would affect the flight of the projectiles could not be determined with the means at hand. Probably, as regards the accuracy required of these guns, and considering their short ranges, the effect would not be great; but, with the enlargement of the bore, the force of the projectile would undoubtedly be much diminished, owing to the escape of gas around it. It therefore becomes an important matter to issue these guns for service in such a condition that *the bore will not be disadvantageously enlarged by service firing.*

It is well known that mandreling the bore has been resorted to in other cases for effecting this purpose. It is also well known that the bore of a bronze gun once enlarged by a given charge and powder pressure will subsequently stand a number of rounds, with the same or an inferior pressure, without any decided enlargement of the bore. Indeed this is believed to have been in part Captain Lyle's object in prescribing that his guns should be subjected to the 3-proof rounds with a reduced bore, whereby the metal around the bore would be condensed, leaving a safe margin for the finishing cut. In practice, however, this result is not brought about. Of the 135 guns recently constructed none gave a decided enlargement of the bore under the ordinary proof, much less any approach to the "set" of 0.1 inch developed in the bore of (casting) No. 10 under the first three rounds to which it was subjected in the state of a finished gun. But after this first enlargement the maximum increase up to 100 rounds with service charges was but 0.013 inches. The first proof (three rounds) of this gun was made with a charge of 8 ounces of powder and an 18-pound projectile, with the bore 2.45 inches diameter, and there was no appreciable enlargement. The first three rounds after finishing, using practically the same charge, gave a great enlargement. The probable main cause of this difference is due to the difference of the fit of the projectiles in the two cases. In the preliminary proof it was a close fit, but not quite air-tight, as in the after proof, and this arose from the fact that the gun, being "rough bored" for the preliminary proof, the fit of the projectile was not accurate.

These facts lead to the following recommendations in regard to the firing proof of these guns in future constructions. Each gun shall be proved by firing three rounds; for the first two rounds the gun shall be mounted in a carriage similar to the service pattern, and the proof charge shall be 8 ounces of Hazard navy cannon powder, or a finer grained powder made by the same firm, or another to be agreed upon by the contracting parties, and a cylindrical bolt or projectile to weigh not less than 18 pounds. For the third round the gun shall be mounted in a cradle (the trunnions free), and the proof charge shall be 12 ounces of the same powder, and a similar projectile. * * * The powder proof shall be applied before "finishing reaming," the diameter of the bore for the proof to be 2.3 inches, and the proof projectile must be made to fit the bore air-tight preliminary to the first proof round.

The purport of this recommendation is to subject the bore to at least as great a powder pressure as it will afterwards receive in service. The first two rounds with service conditions, including an air-tight projectile, may effect that object, and at the same time will sufficiently test the strength of the *finished* trunnions. But if the first two rounds do not compress the bore, the third and heavier round fired from a cradle will probably do it, and will otherwise certainly produce a powder pressure greater than to be afterwards had in service. From the fact that the trunnions are in a finished state at this proof, and that they are already about the minimum size, consistent with safety, it is considered that they should not be subjected to the heavy proof round which is intended only to insure a proper condensation of the metal around the bore. The two lighter charges are given first, so as to prepare the gun for the heavier charge and not subject the metal suddenly to an excessive strain, the ill effects of which are shown in Lieutenant Whipple's report (see pages 277 and 278, report of the Chief of Ordnance, U. S. A., 1878).

PROJECTILES.

In making the projectiles under this contract there was no change from previous methods except in regard to the projectile "shanks." These had been rough shaped in a die. In this instance they were made from a fine quality of Ulster round bar-iron. The bars were received 1.125 inches in diameter, and cut into lengths of 4.125 inches. The central portion of these lengths was then forged and drawn out nearly to finished size to form the neck of the shank, the two ends being left rough to finish for the head (or eye) and threaded portion. The eye end was first turned to the shape of a sphere joined to the end of the stem; next, two sides of the sphere were removed together by milling to leave the proper "thickness at eye;" finally, the eye-hole was drilled, chamfered, and otherwise finished.

ADDENDA.

Chemical analysis of samples (*contract of December* 14, 1883).

At the close of writing this report there come to hand the results of a chemical analysis of 10 samples, made by Captain Pitman, United

States Ordnance, taken from the 10 specimen pieces sent to Watertown Arsenal for test (a summary of the mechanical tests is given in Table D, and the individual records are appended).

These results are highly interesting and important. The samples pertain to the lower portions of the sinking heads, between the muzzle of the gun proper and about 6 inches upwards (the guns being cast muzzle up). The following table gives the results obtained by the analysis and for comparison the percentage of tin estimated to be in the charge at the time of casting.

TABLE H.

Casting, number of sample.	By analysis.		Original charge estimated to contain—		Lost or gained in melting.	
	Copper.	Tin.	Copper.	Tin.	Copper.	Tin.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
27	90.71	9.14	91.17	8.83	−0.46	+0.31
33	91.33	8.64	91.19	8.81	+0.14	−0.17
47	91.45	8.48	91.47	8.53	−0.02	−0.05
49	91.57	8.42	91.39	8.61	+0.18	−0.19
63	91.64	8.40	91.46	8.54	+0.18	−0.14
71	91.59	8.39	91.46	8.54	+0.13	−0.15
73	91.32	8.23	91.00	9.00	+0.32	−0.77
95	91.79	8.29	91.47	8.53	+0.32	−0.24
97	91.81	8.23	91.47	8.53	+0.34	−0.30
99	91.74	7.76	91.47	8.53	+0.27	−0.77
Averages	91.495	8.398	91.375	8.545	+0.12	−0.147

There is an average relative gain of 0.12 per cent. of copper and relative loss of 0.15 per cent. of tin. The tests being made from numbers of the castings taken at random through the whole list, attest the accuracy with which the original charges were apportioned; they also show that the relative loss of tin in the melting as conducted was a small and nearly constant quantity. The higher numbers show an increase in this loss, for the bronze used in their charges (40 to 45 per cent. of the charge) had been one or more times remelted.

Not less important is that phase of these results which shows the effect of the *actual* percentage of tin present upon the physical qualities of the metal. The samples used for the preceding analysis were taken from the same castings and identically placed with the tensile test pieces, the physical qualities of which are given in Table D. We are thus able to judge of the precise effect of tin upon the physical qualities. The best results were obtained from No. 33, containing 8.64 per cent. of tin, whilst No. 99, containing but 7.76 per cent. of tin, is nearly equal to the best. No. 27, containing the highest percentage of tin (9.14), is near the foot of the list.

CONCLUSIONS.

The results of the chemical analyses, although limited in number and scope, relative to the requirements of the manufacture, yet do not conflict with the rule given, page 397, to the effect that the bronze from the first melting of a given charge may be taken to contain one-fourth of one per cent. less tin than was contained in the original charge.

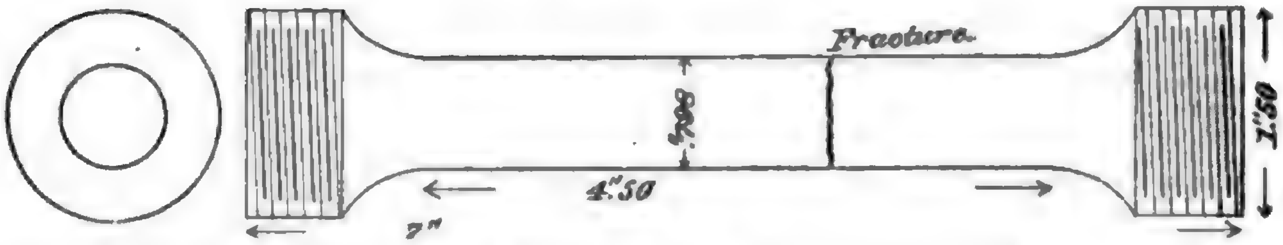
Also having due regard for the behavior of the guns herein described under the firing proof, the precise results of the analysis of pieces tested for physical qualities, and giving due weight to the well-known fact that the hardness of bronze increases with the proportion of tin present, there appears no reason to modify the conclusion previously given that the proportions, copper 91 per cent., tin 9 per cent., represent the best for use as these guns are now made.

REPORT OF MECHANICAL TESTS, MADE WITH THE UNITED STATES TESTING MACHINE, CAPACITY, 800,000 POUNDS, AT WATERTOWN ARSENAL, MASSACHUSETTS, FOR THE ORDNANCE DEPARTMENT, U. S. ARMY, WASHINGTON, D. C.

TESTS BY TENSION: TEN BRONZE SPECIMENS FROM WEST POINT FOUNDRY.

March 22, 1884.

No. 131.



Ends threaded to fit 1.56-inch dies, ten threads per inch. Hence thread not full V.

[Marks on bar, 99; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	....	0.	....	Initial load.
1, 000	2, 000	.000075	.000075	0.	....	
1, 500	3, 000	.000150	.000075	0.	....	
2, 000	4, 000	.000200	.000050	0.	....	
2, 500	5, 000	.000250	.000050	0.	....	
3, 000	6, 000	.000300	.000050	0.	....	
3, 500	7, 000	.000375	.000075	0.	....	
4, 000	8, 000	.000475	.000100	0.	....	
4, 500	9, 000	.000475	0.	0.	....	
5, 000	10, 000	.000525	.000050	0.	....	
5, 500	11, 000	.000550	.000025	0.	....	
6, 000	12, 000	.000625	.000075	0.	....	
6, 500	13, 000	.000750	.000125	0.	....	
7, 000	14, 000	.000800	.000050	0.	....	Elastic limit.
7, 500	15, 000	.000950	.000150	.000075	.000075	
8, 000	16, 000	.001200	.000250	.000225	.000150	
8, 500	17, 000	.001475	.000275	.000425	.000200	
9, 000	18, 000	.001975	.000500	.000800	.000375	
9, 500	19, 000	.002925	.000950	.001750	.000950	
10, 000	20, 000	.004725	.001800	.003525	.001775	
10, 500	21, 000	.007925	.003200	.006775	.003250	
11, 000	22, 000	.014925	.007000	.013475	.006700	
11, 500	23, 000	.019700	.004775	.018075	.004600	
12, 000	24, 000	.027850	.008150	.026225	.008150	
12, 500	25, 000	.034475	.006625	.032625	.006400	
13, 000	26, 000	.042475	.008000	.040375	.007750	
13, 500	27, 000	.050225	.007750	.047975	.007600	
14, 000	28, 000	.058725	.008500	.056425	.008450	
14, 500	29, 000	.067725	.009000	.065225	.008800	
15, 000	30, 000	.077400	.009675	.074525	.009300	Micrometer removed.
15, 500	31, 000	.0875	.0101	....	....	
16, 000	32, 000	.1000	.0125	....	....	
16, 500	33, 000	.1125	.0125	....	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
17, 000	34, 000	. 1250	. 0125	....	....	
17, 500	35, 000	. 1375	. 0125	....	....	
18, 000	36, 000	. 1500	. 0125	....	....	
18, 500	37, 000	. 1650	. 0150	....	....	
19, 000	38, 000	. 1800	. 0150	....	....	
19, 500	39, 000	. 2000	. 0200	....	....	
20, 000	40, 000	. 2175	. 0175	....	....	
20, 500	41, 000	. 2400	. 0225	....	....	
21, 000	42, 000	. 2600	. 0200	....	....	
21, 500	43, 000	. 2875	. 0275	....	....	
22, 000	44, 000	. 3200	. 0325	....	....	
22, 050	44, 100	....	....	....	....	Ultimate strength.

Elongation of inch sections: .35 inch (.41 inch fractured section), .31 inch, .26 inch.

GENERAL SUMMARY.

Specific gravity		8. 6247
Hardness		5. 12
Tensile strength per square inch of original section	pounds	44, 100
Elastic limit per square inch of original section	do	14, 000
Elongation per inch after rupture	inch	0. 33
Elongation per inch under strain at elastic limit	do	. 000800
Reduction in diameter at point of rupture (approximate)	do	. 148
Reduction in area after rupture, per centum of original section		34. 0
Position of rupture		1¾ inches from neck.
Character of broken surface		light yellow, uniform color. Fine surface cracks developed along stem.

No. 149.

[Marks on bar, 49; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	....	0.	....	Initial load.
1, 000	2, 000	. 000075	. 000075	0.	....	
1, 500	3, 000	. 000100	. 000025	0.	....	
2, 000	4, 000	. 000150	. 000050	0.	....	
2, 500	5, 000	. 000225	. 000075	0.	....	
3, 000	6, 000	. 000275	. 000050	0.	....	
3, 500	7, 000	. 000325	. 000050	0.	....	
4, 000	8, 000	. 000375	. 000050	0.	....	
4, 500	9, 000	. 000425	. 000050	0.	....	
5, 000	10, 000	. 000500	. 000075	0.	....	
5, 500	11, 000	. 000550	. 000050	0.	....	
6, 000	12, 000	. 000600	. 000050	0.	....	
6, 500	13, 000	. 000625	. 000025	0.	....	
7, 000	14, 000	. 000675	. 000050	0.	....	Elastic limit.
7, 500	15, 000	. 000825	. 000150	. 000075	. 000075	
8, 000	16, 000	. 000900	. 000075	. 000125	. 000050	
8, 500	17, 000	. 001100	. 000200	. 000250	. 000125	
9, 000	18, 000	. 001300	. 000200	. 000375	. 000125	

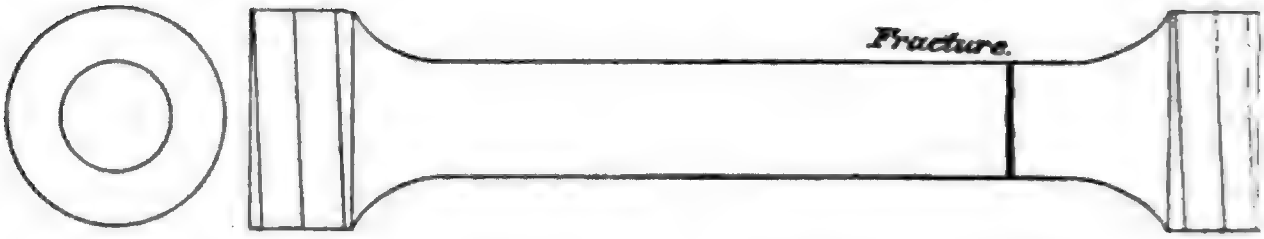
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
9,500	19,000	.001575	.000275	.000600	.000225	
10,000	20,000	.002100	.000525	.001125	.000525	
10,500	21,000	.003800	.001700	.002850	.001725	
11,000	22,000	.005325	.001525	.004400	.001550	
11,500	23,000	.010100	.004775	.008900	.004500	
12,000	24,000	.014250	.004150	.013050	.004150	
12,500	25,000	.019525	.005275	.018100	.005050	
13,000	26,000	.025825	.006300	.024325	.006225	
13,500	27,000	.032575	.006750	.030825	.006500	
14,000	28,000	.039325	.006750	.037575	.006750	
14,500	29,000	.046000	.006675	.044100	.006525	
15,000	30,000	.053575	.007575	.051525	.007425	Micrometer removed.
15,500	31,000	.0625	.008925	....	....	
16,000	32,000	.0700	.0075	....	....	
16,500	33,000	.0800	.0100	....	....	
17,000	34,000	.0900	.0100	....	....	
17,500	35,000	.1000	.0100	....	....	
18,000	36,000	.1125	.0125	....	....	
18,500	37,000	.1225	.0100	....	....	
19,000	38,000	.1350	.0125	....	....	
19,500	39,000	.1475	.0125	....	....	
20,000	40,000	.1600	.0125	....	....	
20,500	41,000	.1700	.0100	....	....	
21,000	42,000	.1925	.0225	....	....	
21,500	43,000	.2025	.0100	....	....	
22,000	44,000	.2250	.0225	....	....	
22,500	45,000	.2450	.0200	....	....	
23,000	46,000	.2675	.0225	....	....	
23,500	47,000	.2900	.0225	....	....	
24,000	48,000	.3175	.0225	....	....	
24,500	49,000	.3575	.0400	....	....	
25,000	50,000	.3925	.0350	....	....	
25,500	51,000	.4450	.0525	....	....	
25,580	51,160	....	....	....	....	Ultimate strength.

Elongation of inch sections: (.54 inch fractured section), .45 inch, .43 inch .42 inch.

GENERAL SUMMARY.

Specific gravity	8.8940
Hardness	7.16
Tensile strength per square inch of original section ... pounds..	51,160
Elastic limit per square inch of original section ... do....	14,000
Elongation per inch after rupture ... inch..	0.46
Elongation per inch under strain at elastic limit ... do....	.000675
Reduction in diameter at point of rupture (approximate) ... do....	.188
Reduction in area after rupture, per centum of original section	42.0
Position of rupture	1.3 inches from neck.
Character of broken surface	uniform structure, light yellow color.

No. 150.



[Marks on bar, 73; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	....	0.	....	Initial load.
1,000	2,000	.000050	.000050	0.	....	
1,500	3,000	.000125	.000075	0.	....	
2,000	4,000	.000200	.000075	0.	....	
2,500	5,000	.000250	.000050	.000025	.000025	
3,000	6,000	.000300	.000050	.000025	0.	
3,500	7,000	.000400	.000100	.000025	0.	
4,000	8,000	.000500	.000100	.000025	0.	
4,500	9,000	.000525	.000025	.000025	0.	
5,000	10,000	.000600	.000075	.000025	0.	Elastic limit.
5,500	11,000	.000700	.000100	.000075	.000050	
6,000	12,000	.000750	.000050	.000100	.000025	
6,500	13,000	.000850	.000100	.000150	.000050	
7,000	14,000	.000975	.000125	.000200	.000050	
7,500	15,000	.001025	.000050	.000225	.000025	
8,000	16,000	.001175	.000150	.000300	.000075	
8,500	17,000	.001350	.000175	.000400	.000100	
9,000	18,000	.001550	.000200	.000525	.000125	
9,500	19,000	.001850	.000300	.000750	.000225	
10,000	20,000	.002250	.000400	.001025	.000275	
10,500	21,000	.002825	.000575	.001650	.000625	
11,000	22,000	.003875	.001050	.002750	.001100	
11,500	23,000	.005050	.001175	.003775	.001025	
12,000	24,000	.007025	.001975	.005750	.001975	
12,500	25,000	.009825	.002800	.008400	.002650	
13,000	26,000	.012750	.002925	.011175	.002775	
13,500	27,000	.014550	.001800	.013025	.001850	
14,000	28,000	.019500	.004950	.017800	.004775	
14,500	29,000	.024125	.004625	.022175	.004375	
15,000	30,000	.030000	.005875	.027850	.005675	Micrometer removed.
15,500	31,000	.0350	.0050	....	....	
16,000	32,000	.0400	.0050	....	....	
16,500	33,000	.0450	.0050	....	....	
17,000	34,000	.0575	.0125	....	....	
17,500	35,000	.0625	.0050	....	....	
18,000	36,000	.0700	.0075	....	....	
18,500	37,000	.0800	.0100	....	....	
19,000	38,000	.0875	.0075	....	....	
19,500	39,000	.1000	.0125	....	....	
20,000	40,000	.1125	.0125	....	....	
20,500	41,000	.1200	.0075	....	....	
21,000	42,000	.1325	.0125	....	....	
21,500	43,000	.1500	.0175	....	....	
22,000	44,000	.1600	.0100	....	....	
22,500	45,000	.1825	.0225	....	....	
23,000	46,000	.2000	.0175	....	....	
23,500	47,000	.2200	.0200	....	....	
24,000	48,000	.2450	.0250	....	....	
24,500	49,000	.2750	.0300	....	....	
25,000	50,000	.3075	.0325	....	....	
25,500	51,000	.3475	.0400	....	....	
25,700	51,400	....	....	....	....	Ultimate strength.

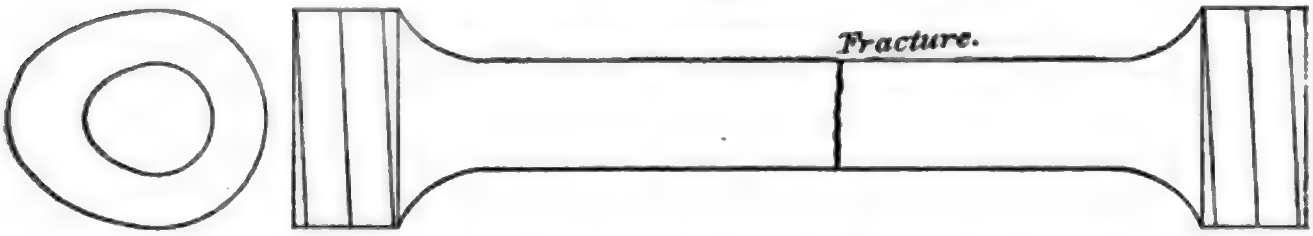
Elongation of inch sections: (.41 inch fractured section), .35 inch, .34 inch, .33 inch.

The stem preserved its cylindrical form during the test, not drawing down and making an irregular surface, characteristic of the more ductile specimens.

GENERAL SUMMARY.

Specific gravity	8.8350
Hardness	7.40
Tensile strength per square inch of original section pounds	51,400
Elastic limit per square inch of original section do.	10,000
Elongation per inch after rupture inch	0.357
Elongation per inch under strain at elastic limit do.	.000600
Reduction in diameter at point of rupture do.	.138
Reduction in area after rupture, per centum of original section	32.0
Position of rupture	one-half inch from neck.
Character of broken surface	yellowish gray. Surface cracks developed along the stem.

No. 151.



[Marks on bar 97; diameter, .798 inch; sectional area, .50 square inch.]

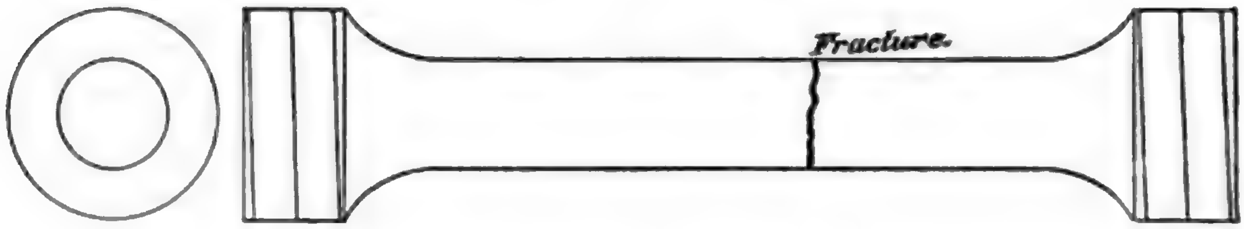
Applied loads.		Elongation per inch	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	....	0.	....	Initial load.
1,000	2,000	.000050	.000050	0.	....	
1,500	3,000	.000125	.000075	0.	....	
2,000	4,000	.000175	.000050	0.	....	
2,500	5,000	.000250	.000075	0.	....	
3,000	6,000	.000275	.000025	0.	....	
3,500	7,000	.000325	.000050	0.	....	
4,000	8,000	.000375	.000050	0.	....	
4,500	9,000	.000450	.000075	0.	....	
5,000	10,000	.000500	.000050	0.	....	
5,500	11,000	.000550	.000050	0.	....	
6,000	12,000	.000625	.000075	0.	....	
6,500	13,000	.000700	.000075	0.	....	Elastic limit.
7,000	14,000	.000775	.000075	.000025	.000025	
7,500	15,000	.000875	.000100	.000075	.000050	
8,000	16,000	.001025	.000150	.000200	.000125	
8,500	17,000	.001250	.000225	.000300	.000100	
9,000	18,000	.001500	.000250	.000525	.000225	
9,500	19,000	.001800	.000300	.000875	.000350	
10,000	20,000	.002525	.000725	.001550	.000675	
10,500	21,000	.003950	.001425	.003050	.001500	
11,000	22,000	.006275	.002325	.005225	.002175	
11,500	23,000	.010050	.003775	.008950	.003725	
12,000	24,000	.014975	.004925	.013750	.004800	
12,500	25,000	.020525	.005550	.019025	.005275	
13,000	26,000	.026475	.005950	.025025	.006000	
13,500	27,000	.032025	.005550	.030525	.005500	
14,000	28,000	.040025	.008000	.038225	.007700	
14,500	29,000	.047275	.007250	.045525	.007300	
15,000	30,000	.055525	.008250	.053425	.007900	Micrometer removed.
15,500	31,000	.0650	.009475	....	....	
16,000	32,000	.0725	.0075	....	....	
16,500	33,000	.0800	.0075	....	....	
17,000	34,000	.0925	.0125	....	....	
17,500	35,000	.1025	.0100	....	....	
18,000	36,000	.1125	.0100	....	....	
18,500	37,000	.1250	.0125	....	....	
19,000	38,000	.1375	.0125	....	....	
19,500	39,000	.1525	.0150	....	....	
20,000	40,000	.1650	.0125	....	....	
20,500	41,000	.1825	.0175	....	....	
21,000	42,000	.2000	.0175	....	....	
21,500	43,000	.2200	.0200	....	....	
22,000	44,000	.2375	.0175	....	....	
22,500	45,000	.2625	.0250	....	....	
23,000	46,000	.2850	.0175	....	....	
23,500	47,000	.3125	.0275	....	....	
24,000	48,000	.3475	.0350	....	....	
24,500	49,000	.3875	.0400	....	....	
25,000	50,000	.4375	.0500	....	....	
25,490	50,980	....	....	....	....	Ultimate strength.

Elongation of inch sections: .53 inch, .49 inch (.56 inch fractured section), .46 inch.

GENERAL SUMMARY.

Specific gravity	8.8212
Hardness	6.07
Tensile strength per square inch of original section ....pounds..	50,980
Elastic limit per square inch of original section ....do...	13,000
Elongation per inch after rupture ....inch..	0.51
Elongation per inch under strain at elastic limit ....do...	.000700
Reduction in diameter at point of rupture ....do...	.178
Reduction in area after rupture, per centum of original section	40.6
Position of rupture	2 inches from neck.
Character of broken surface	light yellow colored, interspersed with small spots of dark yellow metal.

No. 152.



[Marks on bar, 33; diameter, .798 inch; sectional area .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	....	0.	....	Initial load.
1,000	2,000	.000025	.000025	0.	....	
1,500	3,000	.000075	.000050	0.	....	
2,000	4,000	.000125	.000050	0.	....	
2,500	5,000	.000175	.000050	0.	....	
3,000	6,000	.000225	.000050	0.	....	
3,500	7,000	.000250	.000025	0.	....	
4,000	8,000	.000300	.000050	—.0 0025	.000025	
4,500	9,000	.000350	.000050	—.000025	0.	
5,000	10,000	.000400	.000050	—.000025	0.	
5,500	11,000	.000450	.000050	—.000025	0.	
6,000	12,000	.000525	.000075	—.000025	0.	
6,500	13,000	.000550	.000025	—.000025	0.	
7,000	14,000	.000650	.000100	0.	.000025	
7,500	15,000	.000725	.000075	0.	0.	Elastic limit.
8,000	16,000	.000825	.000100	.000025	.000025	
8,500	17,000	.001000	.000175	.000100	.000075	
9,000	18,000	.001125	.000125	.000175	.000075	
9,500	19,000	.001325	.000200	.000300	.000125	
10,000	20,000	.001625	.000300	.000575	.000275	
10,500	21,000	.002275	.000550	.001250	.000675	
11,000	22,000	.003475	.001200	.002425	.001175	
11,500	23,000	.005825	.002350	.004675	.002250	
12,000	24,000	.010250	.004425	.009050	.004375	
12,500	25,000	.014200	.003950	.012800	.003750	
13,000	26,000	.020000	.005800	.018450	.005650	
13,500	27,000	.025950	.005950	.024400	.005950	
14,000	28,000	.032375	.006425	.030625	.006225	
14,500	29,000	.040250	.007875	.038425	.007800	
15,000	30,000	.946500	.006250	.044500	.006075	Micrometer removed.
15,500	31,000	.0550	.0085	....	....	
16,000	32,000	.0675	.0125	....	....	
16,500	33,000	.0750	.0075	....	....	
17,000	34,000	.0850	.0100	....	....	
17,500	35,000	.0950	.0100	....	....	
18,000	36,000	.1050	.0100	....	....	
18,500	37,000	.1175	.0125	....	....	
19,000	38,000	.1300	.0125	....	....	
19,500	39,000	.1450	.0150	....	....	
20,000	40,000	.1550	.0100	....	....	
20,500	41,000	.1725	.0175	....	....	
21,000	42,000	.1875	.0150	....	....	
21,500	43,000	.2050	.0175	....	....	
22,000	44,000	.2250	.0200	....	....	
22,500	45,000	.2425	.0175	....	....	

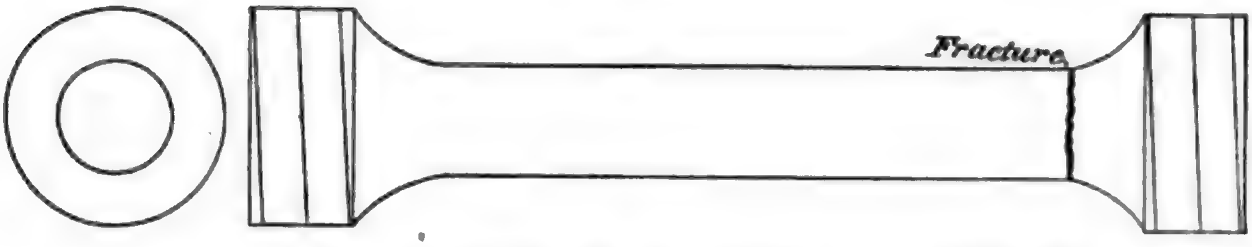
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
23, 000	46, 000	.2650	.0225	....	....	
23, 500	47, 000	.2950	.0300	....	....	
24, 000	48, 000	.3125	.0175	....	....	
24, 500	49, 000	.3450	.0325	....	....	
25, 000	50, 000	.3850	.0400	....	....	
25, 500	51, 000	.4250	.0400	....	....	
26, 000	52, 000	.4975	.0725	....	....	
26, 050	52, 100	....	....	....	....	Ultimate strength.

Elongation of inch sections: .50 inch, .49 inch (.61 inch fractured section), .45 inch.

GENERAL SUMMARY.

Specific gravity		8. 8834
Hardness		6. 13
Tensile strength per square inch of original section	pounds	52, 100
Elastic limit per square inch of original section	do	15, 000
Elongation per inch after rupture	inch	0. 512
Elongation per inch under strain at elastic limit	do	.000725
Reduction in diameter at point of rupture	do	.198
Reduction in area after rupture, per centum of original section		44. 0
Position of rupture		one-half inch from middle of stem.
Character of broken surface		uniform structure, light yellow color.

No. 153.



[Marks on bar, 47; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	....	0.	....	
1, 000	2, 000	.000050	.000050	0.	....	
1, 500	3, 000	.000075	.000025	0.	....	
2, 000	4, 000	.000125	.000050	0.	....	
2, 500	5, 000	.000250	.000125	0.	....	
3, 000	6, 000	.000300	.000050	0.	....	
3, 500	7, 000	.000350	.000050	0.	....	
4, 000	8, 000	.000450	.000100	.000025	.000025	
4, 500	9, 000	.000500	.000050	.000025	0.	
5, 000	10, 000	.000550	.000050	.000025	0.	
5, 500	11, 000	.000675	.000125	.000025	0.	
6, 000	12, 000	.000725	.000050	.000050	.000025	
6, 500	13, 000	.000775	.000050	.000050	0.	Elastic limit.
7, 000	14, 000	.000900	.000125	.000100	....	
7, 500	15, 000	.001025	.000125	.000175	....	
8, 000	16, 000	.001175	.000150	.000275	....	
8, 500	17, 000	.001525	.000350	.000525	....	
9, 000	18, 000	.001800	.000275	.000775	....	
9, 500	19, 000	.002575	.000775	.001475	....	
10, 000	20, 000	.004025	.001450	.002925	....	
10, 500	21, 000	.006225	.002200	.004975	....	
11, 000	22, 000	.009775	.003550	.008575	....	

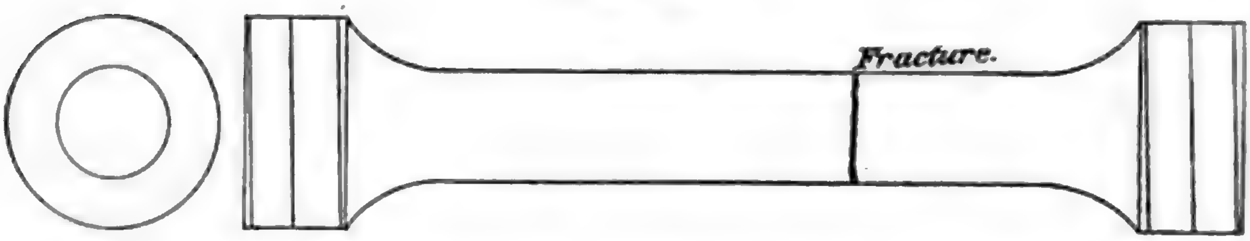
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
11, 500	23, 000	.014350	.004575	.013025	....	
12, 000	24, 000	.021400	.007050	.019775	....	
12, 500	25, 000	.028275	.006875	.026450	....	
13, 000	26, 000	.033400	.005125	.031525	....	
13, 500	27, 000	.042525	.009125	.040375	....	
14, 000	28, 000	.052525	.010000	.050275	....	
14, 500	29, 000	.058525	.006000	.056200	....	
15, 000	30, 000	.069775	.011250	.067200	....	Micrometer removed.
15, 500	31, 000	.0850	.015225	....	....	
16, 000	32, 000	.0925	.0075	....	....	
16, 500	33, 000	.1000	.0075	....	....	
17, 000	34, 000	.1150	.0150	....	....	
17, 500	35, 000	.1275	.0125	....	....	
18, 000	36, 000	.1425	.0150	....	....	
18, 500	37, 000	.1550	.0125	....	....	
19, 000	38, 000	.1725	.0175	....	....	
19, 500	39, 000	.1875	.0150	....	....	
20, 000	40, 000	.2075	.0200	....	....	
20, 500	41, 000	.2275	.0275	....	....	
21, 000	42, 000	.2500	.0225	....	....	
21, 500	43, 000	.2725	.0225	....	....	
22, 000	44, 000	.3075	.0350	....	....	
22, 350	44, 700	....	....	....	....	Ultimate strength.

Elongation of inch sections: .29 inch, .31 inch, .32 inch, .36 inch.

GENERAL SUMMARY.

Specific gravity		8. 6322
Hardness		5. 38
Tensile strength per square inch of original section	pounds..	44, 700
Elastic limit per square inch of original section	do....	13, 000
Elongation per inch after rupture	inch..	0. 32
Elongation per inch under strain at elastic limit	do	.000775
Reduction in diameter at point of rupture		Fractured at neck.
Character of broken surface		porous, spongy; numerous fine cracks developed along surface of the stem; broken surface yellow, copper colored.

No. 154.



[Marks on bar, 71; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	....	0.	....	
1, 000	2, 000	.000050	.000050	0.	....	
1, 500	3, 000	.000100	.000050	0.	....	
2, 000	4, 000	.000150	.000050	0.	....	
2, 500	5, 000	.000200	.000050	0.	....	
3, 000	6, 000	.000250	.000050	0.	....	
3, 500	7, 000	.000300	.000050	0.	....	
4, 000	8, 000	.000350	.000050	0.	....	
4, 500	9, 000	.000425	.000075	0.	....	
5, 000	10, 000	.000475	.000050	0.	....	

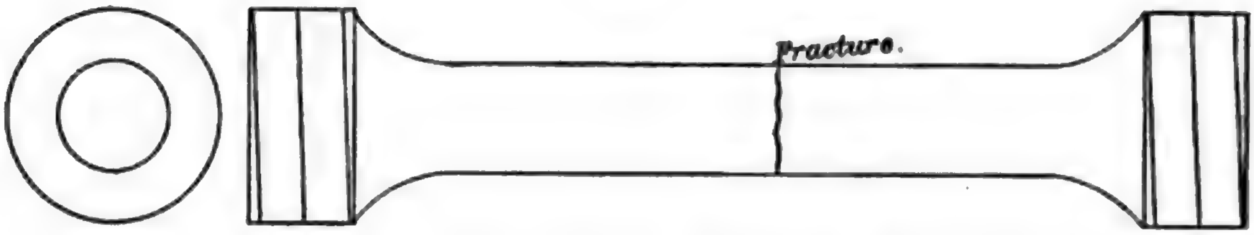
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
5, 500	11, 000	.000525	.000050	0.	....	
6, 000	12, 000	.000625	.000100	0.	....	
6, 500	13, 000	.000725	.000100	.000025	.000025	
7, 000	14, 000	.000775	.000050	.000025	....	Elastic limit.
7, 500	15, 000	.000925	.000150	.000125	....	
8, 000	16, 000	.001075	.000150	.000225	....	
8, 500	17, 000	.001250	.000175	.000350	....	
9, 000	18, 000	.001525	.000275	.000575	....	
9, 500	19, 000	.001925	.000400	.000925	....	
10, 000	20, 000	.003000	.001075	.001975	....	
10, 500	21, 000	.004750	.001750	.003650	....	
11, 000	22, 000	.006550	.001800	.005450	....	
11, 500	23, 000	.009875	.003325	.008700	....	
12, 000	24, 000	.014000	.004125	.012675	....	
12, 500	25, 000	.019200	.005200	.017725	....	
13, 000	26, 000	.022875	.003675	.021250	....	
13, 500	27, 000	.028250	.005375	.026750	....	
14, 000	28, 000	.035250	.007000	.033475	....	
14, 500	29, 000	.042625	.007375	.040650	....	
15, 000	30, 000	.050950	.008325	.048500	....	Micrometer removed.
15, 500	31, 000	.0575	.006550	....	....	
16, 000	32, 000	.0675	.0100	....	....	
16, 500	33, 000	.0750	.0075	....	....	
17, 000	34, 000	.0850	.0100	....	....	
17, 500	35, 000	.0950	.0100	....	....	
18, 000	36, 000	.1050	.0100	....	....	
18, 500	37, 000	.1175	.0125	....	....	
19, 000	38, 000	.1275	.0100	....	....	
19, 500	39, 000	.1375	.0100	....	....	
20, 000	40, 000	.1525	.0150	....	....	
20, 500	41, 000	.1700	.0175	....	....	
21, 000	42, 000	.1875	.0175	....	....	
21, 500	43, 000	.2000	.0125	....	....	
22, 000	44, 000	.2200	.0200	....	....	
22, 500	45, 000	.2400	.0200	....	....	
23, 000	46, 000	.2650	.0250	....	....	
23, 500	47, 000	.2925	.0275	....	....	
23, 900	47, 800	....	....	....	....	Ultimate strength.

Elongation of inch sections: .31 inch, .31 inch (.38 inch fractured section), .33 inch.

GENERAL SUMMARY.

Specific gravity	8.9852
Hardness	6.71
Tensile strength per square inch of original section ....pounds..	47, 800
Elastic limit per square inch of original section ....do...	14, 000
Elongation per inch after rupture ....inch..	0.33
Elongation per inch under strain at elastic limit ....do...	.000775
Reduction in diameter at point of rupture ....do...	.148
Reduction in area after rupture, per centum of original section	34.0
Position of rupture	1¼ inches from neck.
Character of broken surface	yellow gray color, small spongy spot at circumference. Cracks developed along the stem.

No. 155.



[Marks on bar, 63; diameter, .798 inch; sectional area, .50 square inch.]

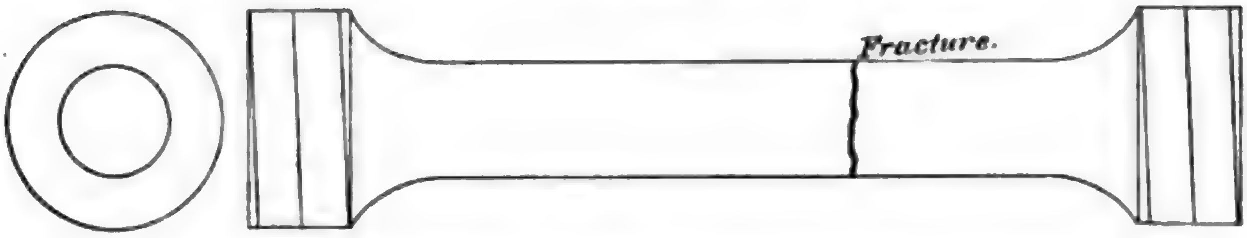
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	....	0.	....	Initial load.
1,000	2,000	.000050	.000050	0.	....	
1,500	3,000	.000125	.000075	0.	....	
2,000	4,000	.000200	.000075	0.	....	
2,500	5,000	.000275	.000075	0.	....	
3,000	6,000	.000375	.000100	—.000025	—.000025	
3,500	7,000	.000425	.000050	—.000025	0.	
4,000	8,000	.000475	.000050	—.000025	0.	
4,500	9,000	.000550	.000075	0.	.000025	Elastic limit.
5,000	10,000	.000650	.000100	.000025	.000025	
5,500	11,000	.000750	.000100	.000050	.000025	
6,000	12,000	.000850	.000100	.000100	.000050	
6,500	13,000	.000925	.000075	.000150	.000050	
7,000	14,000	.001175	.000250	.000275	....	
7,500	15,000	.001425	.000250	.000475	....	
8,000	16,000	.001900	.000475	.000900	....	
8,500	17,000	.002700	.000800	.001650	....	
9,000	18,000	.004275	.001575	.003150	....	
9,500	19,000	.006525	.002250	.005400	....	
10,000	20,000	.011525	.005000	.010325	....	
10,500	21,000	.016900	.005375	.015525	....	
11,000	22,000	.023900	.007000	.022550	....	
11,500	23,000	.031100	.007200	.029400	....	
12,000	24,000	.040575	.009475	.038725	....	
12,500	25,000	.048400	.007925	.046600	....	
13,000	26,000	.059900	.011500	.057825	....	
13,500	27,000	.065900	.006000	.066275	....	
14,000	28,000	.080400	.014500	.078200	....	
14,500	29,000	.091325	.010925	.088650	....	
15,000	30,000	.106100	.014775	.103150	....	Micrometer removed.
15,500	31,000	.1225	.0164	....	....	
16,000	32,000	.1350	.0125	....	....	
16,500	33,000	.1500	.0150	....	....	
17,000	34,000	.1625	.0125	....	....	
17,500	35,000	.1925	.0300	....	....	
17,950	35,900	....	....	....	....	Ultimate strength.

Elongation of inch sections, .20 inch, .20 inch (.29 inch fractured section), .18 inch.

GENERAL SUMMARY.

Specific gravity		8.3696
Hardness		4.78
Tensile strength per square inch of original section	pounds..	35,900
Elastic limit per square inch of original section	do...	9,000
Elongation per inch after rupture	inch..	0.217
Elongation per inch under strain at elastic limit	do...	.000550
Reduction in diameter at point of rupture	do...	.088
Reduction in area after rupture, per centum of original section		20.0
Position of rupture		2 inches from middle of stem.
Character of broken surface		spongy; color light yellow with spots of dark yellow and copper-colored metal. Surface of stem cracked.

No. 156.



[Marks on bar, 95; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	....	0.	....	Initial load.
1,000	2,000	.000075	.000075	0.	....	
1,500	3,000	.000125	.000050	0.	....	
2,000	4,000	.000225	.000100	0.	....	
2,500	5,000	.000275	.000050	0.	....	
3,000	6,000	.000300	.000025	0.	....	
3,500	7,000	.000350	.000050	0.	....	
4,000	8,000	.000425	.000075	0.	....	
4,500	9,000	.000500	.000075	0.	....	
5,000	10,000	.000550	.000050	0.	....	
5,500	11,000	.000625	.000075	0.	....	Elastic limit.
6,000	12,000	.000725	.000100	.000050	.000050	
6,500	13,000	.000775	.000050	.000075	.000025	
7,000	14,000	.000900	.000125	.000175	.000100	
7,500	15,000	.001000	.000100	.000250	.000075	
8,000	16,000	.001300	.000300	.000375	.000125	
8,500	17,000	.001525	.000225	.000550	.000175	
9,000	18,000	.002075	.000550	.001050	.000500	
9,500	19,000	.002950	.000875	.001850	.000800	
10,000	20,000	.005050	.002100	.004000	.002150	
10,500	21,000	.007675	.002625	.006500	.002500	
11,000	22,000	.012200	.004525	.010925	.004425	
11,500	23,000	.016050	.003850	.014700	.003775	
12,000	24,000	.021250	.005200	.019750	.005050	
12,500	25,000	.028000	.006750	.026375	.006625	
13,000	26,000	.036075	.008075	.034250	.007875	
13,500	27,000	.041500	.005425	.039525	.005275	
14,000	28,000	.049075	.007575	.047000	.007475	
14,500	29,000	.057500	.008425	.055300	.008300	Micrometer removed.
15,000	30,000	.066875	.009375	.064625	.009325	
15,500	31,000	.0750	.008125	....	....	
16,000	32,000	.0850	.0100	....	....	
16,500	33,000	.0950	.0100	....	....	
17,000	34,000	.1050	.0100	....	....	
17,500	35,000	.1175	.0125	....	....	
18,000	36,000	.1325	.0150	....	....	
18,500	37,000	.1425	.0100	....	....	
19,000	38,000	.1550	.0125	....	....	
19,500	39,000	.1750	.0200	....	....	
20,000	40,000	.1925	.0175	....	....	
20,500	41,000	.2125	.0200	....	....	
21,000	42,000	.2325	.0200	....	....	
21,500	43,000	.2600	.0275	....	....	
21,840	43,680	....	....	....	....	Ultimate strength.

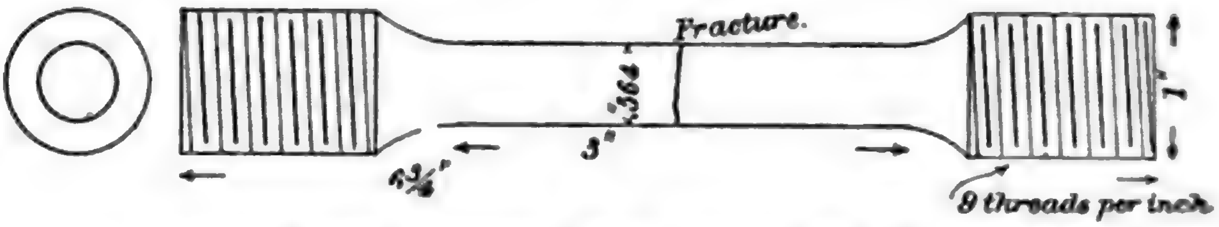
Elongation of inch sections; .25 inch, .27 inch (.33 inch fractured section), .26 inch.

Fracture began at side, showing small copper-colored spots and light-gray metal. This side of the stem was broken with surface cracks.

GENERAL SUMMARY.

Specific gravity	8.7650
Hardness	5.32
Tensile strength per square inch of original section ....pounds..	43,680
Elastic limit per square inch of original section ....do...	11,000
Elongation per inch after rupture ....inch..	0.277
Elongation per inch under strain at elastic limit ....do...	.000625
Reduction in diameter at point of rupture ....do...	.128
Reduction in area after rupture, per centum of original section	30.0
Position of rupture	1¼ inches from neck.
Character of broken surface	slightly spongy; variations of color.

No. 157.



[Marks on bar, 27; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	....	0.	....	Initial load.
500	2, 000	.000100	.000100	0.	....	
750	3, 000	.000233	.000133	.000033	.000033	
1, 000	4, 000	.000300	.000067	.000033	0.	
1, 250	5, 000	.000367	.000067	.000067	.000034	
1, 500	6, 000	.000433	.000066	.000067	0.	
1, 750	7, 000	.000567	.000134	.000067	0.	
2, 000	8, 000	.000600	.000033	.000067	0.	
2, 250	9, 000	.000667	.000067	.000100	.000033	
2, 500	10, 000	.000800	.000133	.000133	.000033	
2, 750	11, 000	.000867	.000067	.000133	0.	
3, 000	12, 000	.000967	.000100	.000167	.000034	Elastic limit.
3, 250	13, 000	.001033	.000066	.000233	.000066	
3, 500	14, 000	.001233	.000200	.000300	.000067	
3, 750	15, 000	.001333	.000100	.000333	.000033	
4, 000	16, 000	.001633	.000300	.000567	.000234	
4, 250	17, 000	.001933	.000300	.000733	.000166	
4, 500	18, 000	.002300	.000367	.001033	.000300	
4, 750	19, 000	.003033	.000733	.001833	.000800	
5, 000	20, 000	.004133	.001100	.002900	.001067	
5, 250	21, 000	.006067	.001934	.004633	.001733	
5, 500	22, 000	.009400	.003333	.007867	.003234	
5, 750	23, 000	.011233	.001833	.010033	.002166	
6, 000	24, 000	.013300	.002067	.014900	.004867	
6, 250	25, 000	.022300	.009000	.020733	.005833	
6, 500	26, 000	.028967	.006667	.027000	.006267	
6, 750	27, 000	.036633	.007666	.034167	.007167	
7, 000	28, 000	.048300	.011667	.045433	.011266	
7, 250	29, 000	.056567	.008267	.053600	.008167	
7, 500	30, 000	.067467	.010900	.064300	.010700	Micrometer removed.
7, 750	31, 000	.0733	.005833	....	....	
8, 000	32, 000	.0867	.0134	....	....	
8, 250	33, 000	.0933	.0066	....	....	
8, 500	34, 000	.1133	.0200	....	....	
8, 750	35, 000	.1233	.0100	....	....	
9, 000	36, 000	.1367	.0134	....	....	
9, 250	37, 000	.1500	.0133	....	....	
9, 500	38, 000	.1600	.0100	....	....	
9, 750	39, 000	.1800	.0200	....	....	
10, 000	40, 000	.1967	.0167	....	....	
10, 250	41, 000	.2167	.0200	....	....	
10, 500	42, 000	.2400	.0233	....	....	
10, 750	43, 000	.2633	.0233	....	....	
10, 880	43, 520	....	....	....	....	Ultimate strength.

Elongation of inch sections: .26 inch (.32 inch fractured section), .26 inch.

GENERAL SUMMARY.

Specific gravity		8.5916
Hardness		5.27
Tensile strength per square inch of original section	pounds..	43,520
Elastic limit per square inch of original section	do ...	12,000
Elongation per inch after rupture	inch..	0.28
Elongation per inch under strain at elastic limit	do...	.000967
Reduction in diameter at point of rupture	do...	.064
Reduction in area after rupture, per centum of original section		28.[illegible]
Position of rupture		Middle of stem.
Character of broken surface		light yellow; slight variation in color

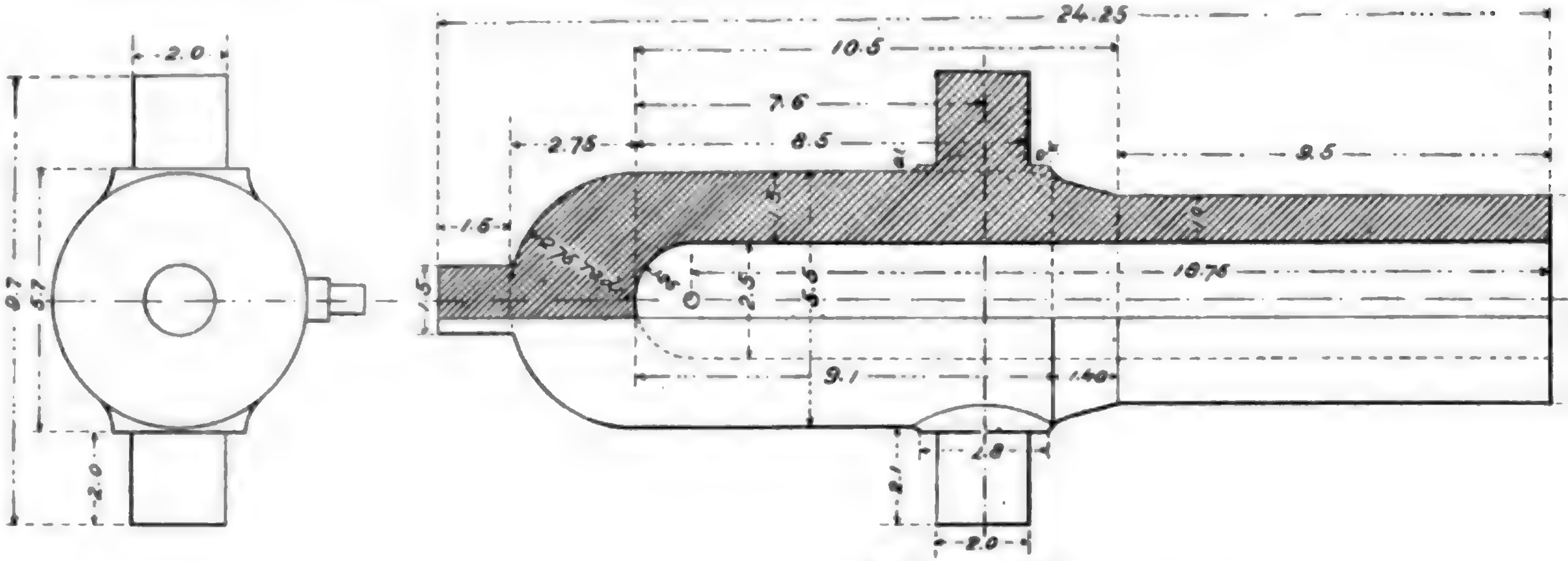
NOTE.—The specific gravities were not determined from the test pieces, but duplicate samples.

In determining hardness a pyramidal indenting tool was used, employing pressures of 5,000 pounds, on account of the smallness of the specimens.

The results were reduced by computation to hardness under 10,000 pounds pressure, assuming that the indentations vary as the square roots of the cubes of the pressures.

F. H. PARKER,
Major Ordnance Department, U. S. Army, Commanding.

PLATE I.



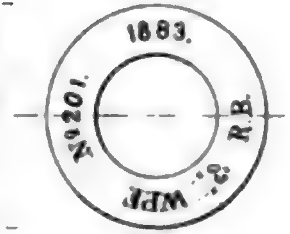


Fig. 2.
MARKS ON
FACE OF MUZZLE

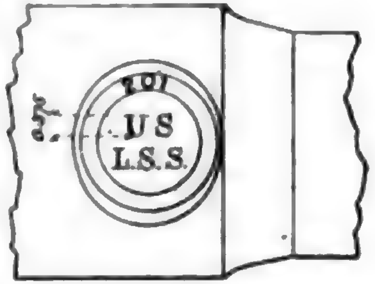
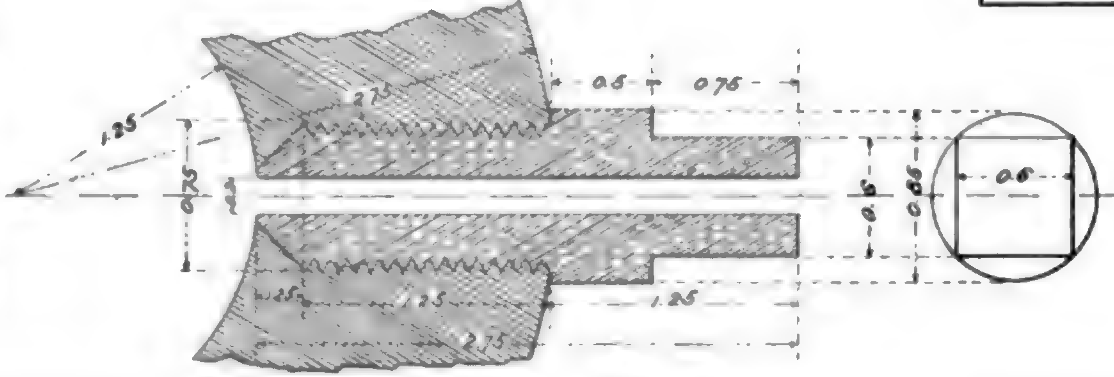


Fig. 4.
MARKS ON
RIGHT TRUNNION.

Scale of inches

DETAILS OF VENT PIECE

Fig. 5.



LIFE-SAVING APPARATUS.

BRONZE GUN.

2½ Inch, Smooth Bore.

DESIGNED BY
Lieut. D. A. LYLE, Ordnance Department, U. S. Army.
AUGUST 14, 1877.

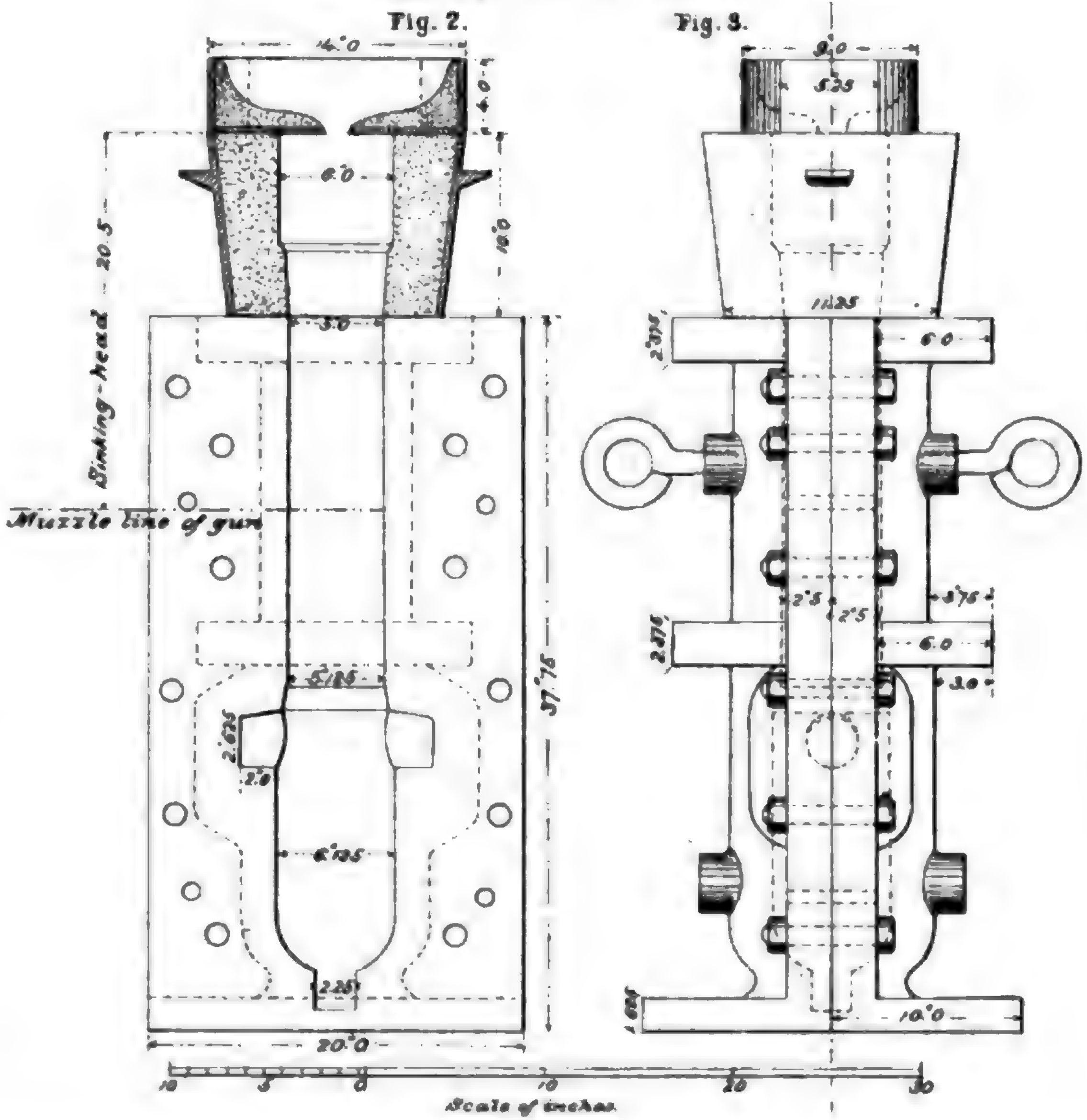
Appendix 28—1884.

PLATE II.

CHILL AND SAND-HEAD ARRANGED FOR CASTING

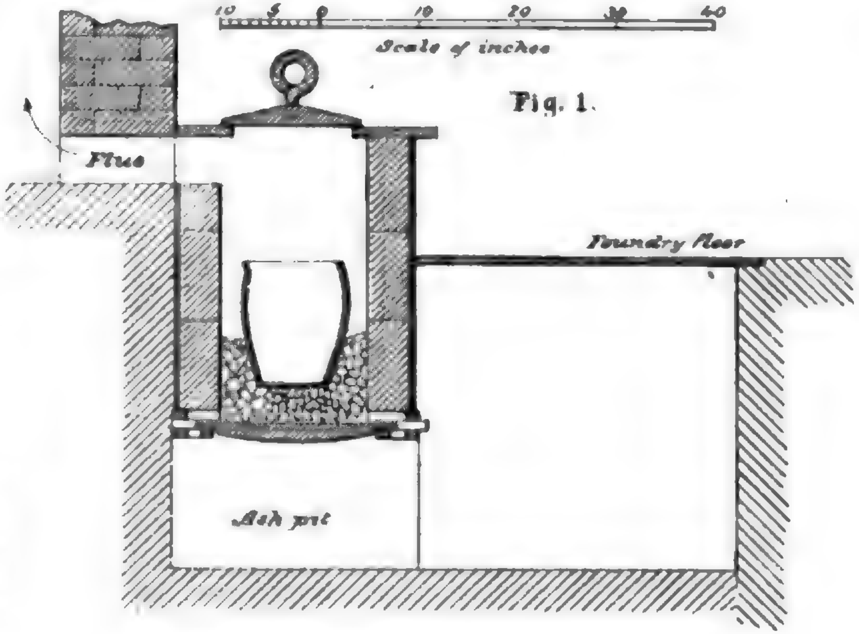
Weight of chill, 1440 pounds.

Fig. 2. Fig. 3.



SKETCH OF FURNACE

Fig. 1.

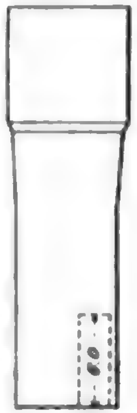


Appendix 28—1884.

PLATE III.

SINKING HEAD

Fig. 1.



PROFILE TEMPLET FOR EXTERIOR LENGTH

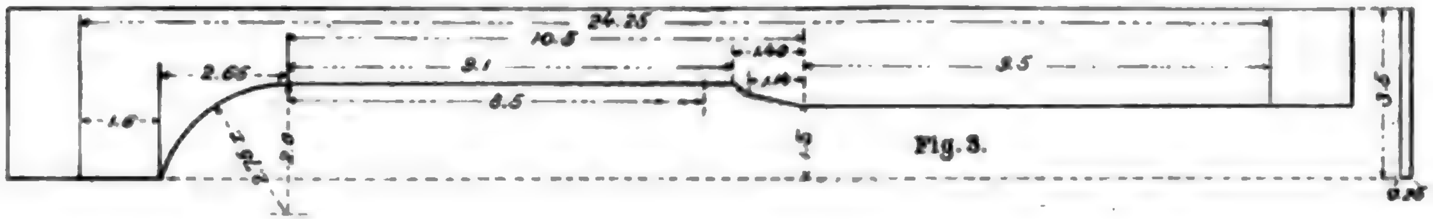
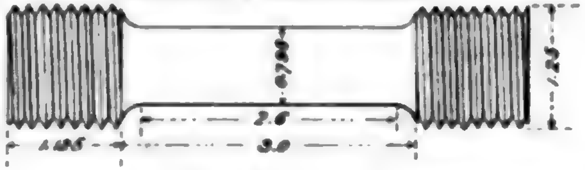


Fig. 3.

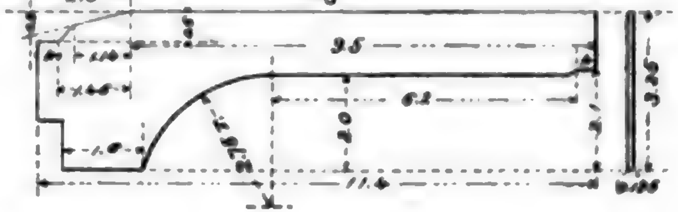
Fig. 2.

TENACITY SPECIMEN



COMBINED CHASE AND BREECH TEMPLET

Fig. 4.



CROSS-TRUNNION TEMPLET

Fig. 5

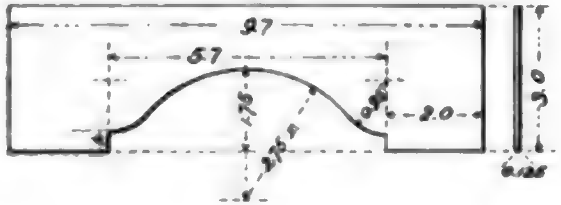
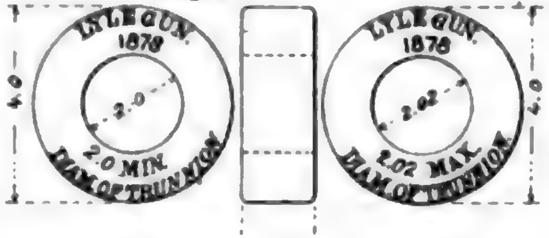
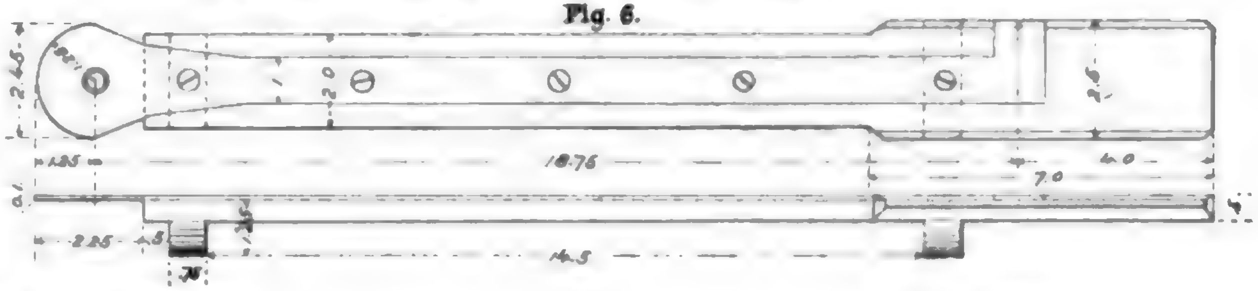


Fig. 7.



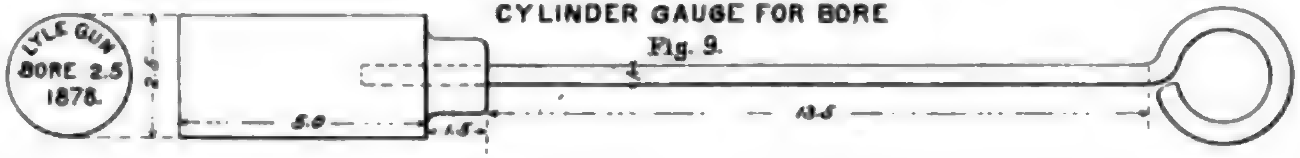
GAUGE FOR POSITION OF VENT, BOTTOM AND LENGTH OF BORE

Fig. 6.



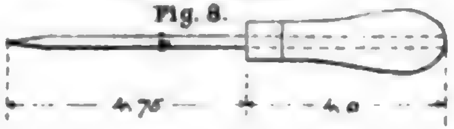
CYLINDER GAUGE FOR BORE

Fig. 9.



VENT GAUGE

Fig. 8.



Appendix 28—1884.

PLATE IV.

PROJECTILE AND GAUGES

Fig. 1.

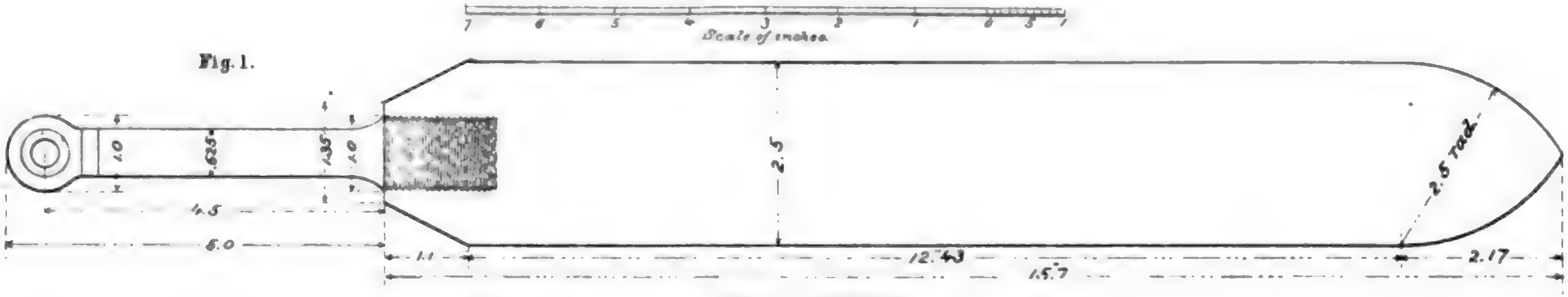
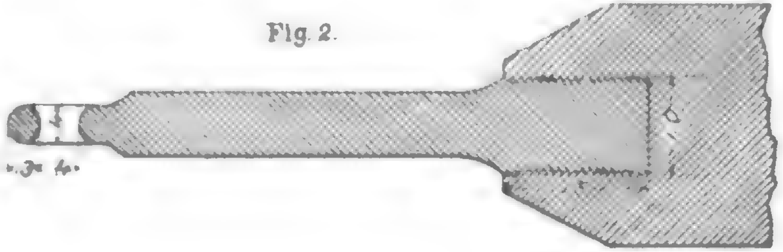
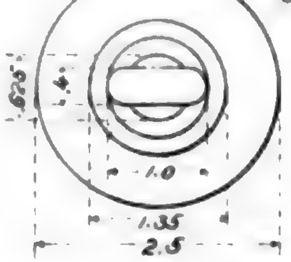


Fig. 2.



REAR ELEVATION

Fig 3.



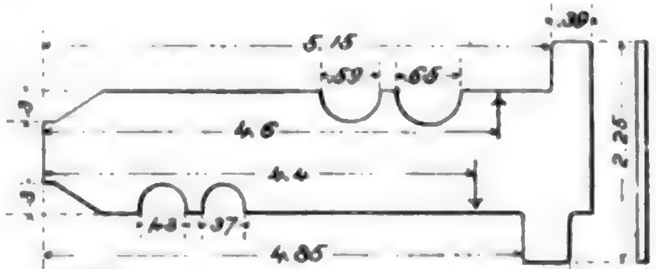
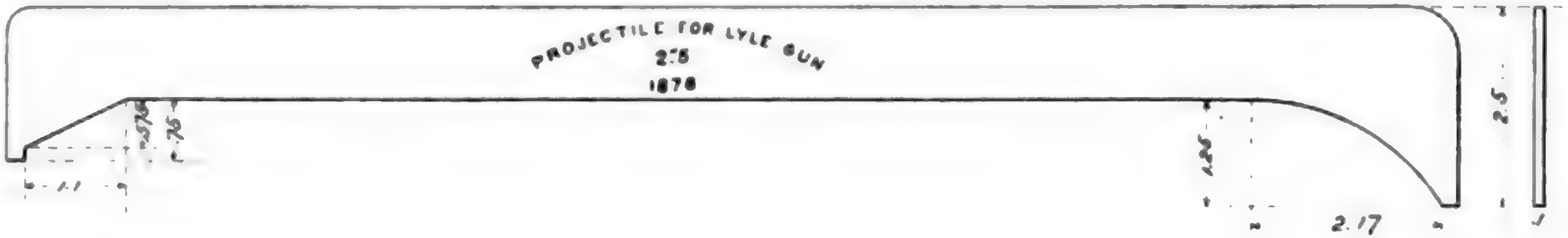


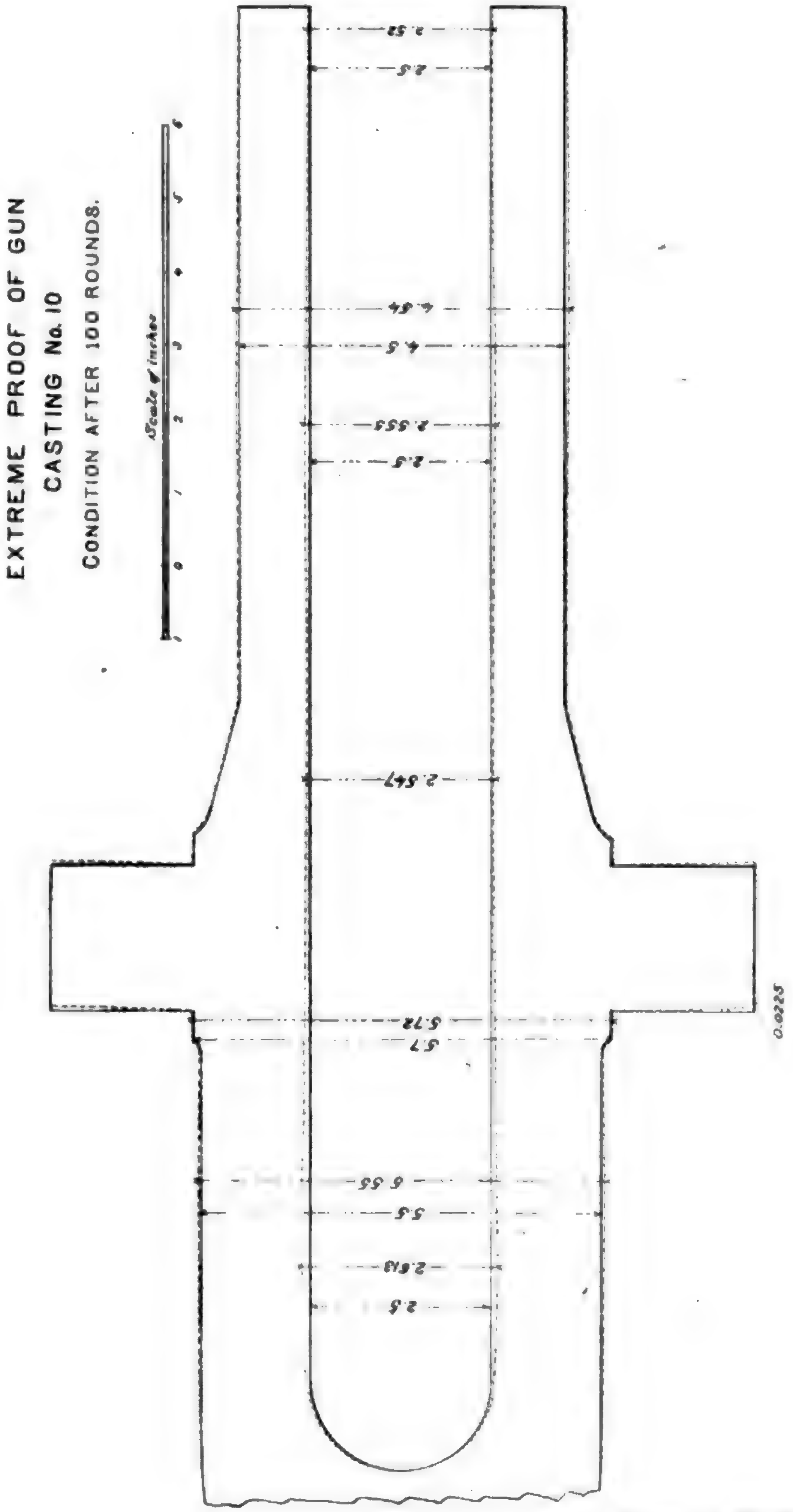
Fig. 4.

GAUSE FOR SHANK

PROFILE FOR PROJECTILE



Appendix 28—1884.



EXTREME PROOF OF GUN
CASTING No. 10
CONDITION AFTER 100 ROUNDS.

Appendix 28—1884.

APPENDIX 29.

REPORT ON THE MANUFACTURE OF STEEL FORGINGS, &C., FOR THE ORDNANCE DEPARTMENT, U. S. A., BY THE MIDVALE STEEL COMPANY DURING THE FISCAL YEAR ENDING JUNE 30, 1884.

BY LIEUT. F. E. HOBBS, ORDNANCE DEPARTMENT.

MIDVALE STEEL WORKS,
Philadelphia, Pa., August 20, 1884.

The CHIEF OF ORDNANCE, U. S. ARMY,
Washington, D. C.:

SIR: Complying with your instructions of the 26th ultimo, I have the honor to submit the following report, showing nature and progress of the work done for the Ordnance Department by the Midvale Steel Company during the fiscal year ending June 30.

During the time specified the Midvale Steel Company undertook to execute for the Department the following contracts or orders for steel gun-hoops, forgings, and castings, viz:

1. Forgings and casting for the parts of a 3.2-inch steel breech-loading field gun.
2. Forgings for tube, breech-cup, and muzzle-collar for converting a 10-inch Rodman smooth-bore gun into an 8-inch muzzle-loading rifle (muzzle insertion).
3. Rolled hoops for a 12-inch muzzle-loading rifled mortar.
4. Hammered rings for a wire-wrapped tube for 12-inch breech loading rifle.
5. Hammered rings for repair of the 6-inch Haskell multicharge gun.
6. Rolled and hammered hoops for an 8-inch steel breech-loading rifle.
7. Forgings for the breech mechanism of 12-inch, 10-inch, and 8-inch breech-loading rifles and casting for 10-inch rifle.
8. Rolled hoops for a 12-inch breech-loading rifle.
9. Rings, forgings, and casting for a 10-inch steel wire-wound breech-loading rifle.

At the end of the fiscal year, those numbered 1, 2, 3, 4, and 5 were completed, and those numbered 6, 7, 8, and 9 were still in hand, those numbered 6 and 7 being, however, nearly completed.*

FORGINGS AND CASTING FOR THE PARTS OF A 3.2-INCH STEEL BREECH-LOADING FIELD GUN.

These parts consisted of tube, jacket, band, base-ring, key-ring, breech-block, carrier-ring, obturator and stem, gas-check and locking-ring forgings, and trunnion band casting of the following rough-finished dimensions, viz:

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*The Midvale Steel Company desire that the details of the manufacture of these forgings, &c., be considered confidential, and for the information of the department only, for the reason that, while no secret or complicated processes are used, the small details of manufacture have been determined by careful experiment and at considerable expense, and it would be comparatively easy for any other firm to copy them. Nearly all information relative to manufacture is therefore omitted in this report.

Nature of piece.	Exterior diameter.	Interior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	6.25	....	86.5	Solid forging.
Jacket	9.20	5.0	20.0	
Band	6.75	4.75	14.55	
Base-ring	6.75	2.75	4.25	
Key-ring	6.50	4.50	1.25	
Breech-block	4.70	1.2 0.6	6.20	With projections.
Carrier-ring	6.75	3.40	1.40	
Obturator and stem	3.8 1.6	....	0.75 7.0	
Gas-check	3.8	2.35	0.75	
Locking-ring	6.7	4.9	3.30	
Trunnion-band	7.75	5.25	9.75	With rim bases and trunnions.

The tube forging was required to be simply annealed, the metal to have an elastic limit of 36,000 pounds per square inch and a tensile strength of 85,000 pounds per square inch. The other forgings and the casting were required to be oil-tempered and subsequently annealed, the metal to have an elastic limit of 42,000 pounds per square inch and a tensile strength of 95,000 pounds per square inch.

The tube forging was made from the lower part of an ingot 15 inches square in cross-section and about 48 inches high, weighing 3,050 pounds; was cooled in dry ashes after forging and subsequently annealed. A tangential test specimen, 2 inches long between shoulders,* taken from the forging after annealing and tested by the Midvale Steel Company, showed: Tensile strength, 87,700 pounds per square inch; elongation after rupture, 16 per cent.; contraction of area, 20 per cent.

The jacket forging was made from part of an ingot 25 inches square in cross-section, and about 50 inches high, weighing 9,450 pounds. The forging was cooled in dry ashes, rough bored, and turned, oil-tempered, and annealed. A tangential specimen, tested by the Midvale Steel Company, then showed: Tensile strength, 102,900 pounds per square inch; elongation after rupture, 14.5 per cent.; contraction of area, 22 per cent.

The band, base-ring, and key-ring forgings were all made from a 15-inch square ingot of the same open hearth heat as the tube and jacket forgings; the band was forged hollow on a mandrel; the base-ring and key-ring were forged solid; all were rough finished and then oil-tempered and annealed. They were treated at the same time and in the same manner as the jacket forging.

The trunnion band was a solid casting of open hearth steel, annealed, oil-tempered, and then again annealed. A tangential specimen, tested by the Midvale Steel Company, showed: Tensile strength, 96,700 pounds per square inch; elongation after rupture, 19.5 per cent.; contraction of area, 40 per cent. The casting was clean and free from blow holes.

The breech-block, carrier-ring, obturator and stem, gas-check and locking-ring forgings for the breech mechanism were made from part of a 15-inch square ingot of the open hearth heat, from which were made the experimental hoops furnished the Department by this company (see reports, Appendices Nos. 41 and 42, Report of the Chief of Ordnance, 1883). After being rough-finished they were oil-tempered and annealed, with a view to obtaining the desired physical qualities.

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*All Midvale specimens are 2 inches long between shoulders.

FORGINGS FOR TUBE, BREECH CUP, AND MUZZLE COLLAR FOR CONVERTING A 10-INCH RODMAN SMOOTH-BORE INTO AN 8-INCH BREECH-LOADING RILE.

These forgings were of the following dimensions, viz:

Nature of piece.	Exterior diameter.	Interior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
Tube	14.5		126.75	Rough forging.
Breech cup	8.65		8.7	Do.
Muzzle collar	13.75	11.25	7.0	Rough finished.

The metal of the tube was required to have a tensile strength of 70,000 pounds per square inch, an elastic limit of 28,000 pounds per square inch, and an elongation after rupture of 20 per cent. in tangential specimens 3 inches long between shoulders. The tube and breech cup to be of like physical qualities, the muzzle collar to be slightly harder.

The tube forging was made from an ingot 30 inches square in cross-section by about 50 inches high, weighing 12,430 pounds. The forged length was about 135.5 inches, the extra metal being cut off for test specimens. In forging the ingot was heated five times and was laid down and chipped between the third and fourth heats. The forging was then annealed, and a tangential specimen taken from the breech end (bottom of ingot), tested by the Midvale Steel Company showed: Tensile strength, 71,500 pounds per square inch; elongation after rupture, 25.5 per cent.; contraction of area, 39.7 per cent. The cylinders for test specimens were then cut from the ends of the forging and the specimens cut out; of these there were one radial and three tangential from the cylinder cut from the muzzle end of the forging and two longitudinal, two radial, and three tangential from the cylinder cut from the breech end of the forging. All the tangential and longitudinal specimens were taken within a prolongation of the exterior and interior surfaces of the finished tube.

The specimens were tested with the United States testing machine at Watertown Arsenal.

The results of the tests are given in the following table:

Results obtained in tensile tests of specimens from forging for tube for 8-inch converted rifle.

Position of specimen.	Dimensions of specimens.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Pounds.*	*Inch.*	*Per cent.*
Tangential, breech end	Length, 3 inches between fillets; diameter, 0.564 inch; sectional area, 0.25 square inch.	38,000	.001400	79,080	.20	27.6
Do		35,000	.001233	79,600	.24	30.8
Do		35,000	.001267	79,600	.24	33.8
Longitudinal, breech end		45,000	.001233	79,880	.307	56.8
Do		40,000	.001367	78,480	.32	56.8
Radial, breech end		33,000	.001200	77,520	.20	30.8
Do		35,000	.001767	75,920	.217	27.6
Tangential, muzzle end		41,000	.001567	82,400	.28	42.0
Do		42,000	.001367	81,000	.237	30.8
Do		40,000	.001167	79,120	.26	42.0
Radial, muzzle end		40,000	.001267	82,000	.18	39.2

Results obtained in tensile tests of specimens from forging for tube, &c.—**Continued.**

Position of specimen.	Elongation, per inch of length, caused by the undermentioned loads.										
	15,000 pounds per square inch.	20,000 pounds per square inch.	25,000 pounds per square inch.	30,000 pounds per square inch.	33,000 pounds per square inch.	38,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	60,000 pounds per square inch.	70,000 pounds per square inch.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Tangential, breech end	.000500	.000633	.000800	.000967	.001100	.001400	.004733	.009100	.01460	.02833	.05316
Do	.000533	.000667	.000867	.001000	.001233	.001700	.004233	.008900	.01373	.02723	.05223
Do	.000533	.000633	.000833	.001000	.001267	.001667	.004967	.005067	.01483	.02796	.05420
Longitudinal, breech end	.000300	.000433	.000600	.000733	.000867	.001000	.001067	.001233	.011067	.02356	.04905
Do	.000400	.000633	.000733	.001000	.001100	.001267	.001367	.008630	.01300	.02733	.05560
Radial, breech end	.000500	.000667	.000833	.001067	.001467	.003200	.00580	.010200	.01583	.03210	.06210
Do	.000633	.000800	.001000	.001300	.001767	.004767	.00630	.011300	.01732	.03367	.06800
Tangential, muzzle end	.000567	.000733	.000900	.001133	.001267	.001433	.001533	.009633	.01440	.02673	.04906
Do	.000433	.000633	.000733	.000933	.001067	.001133	.001233	.010267	.01503	.02930	.05240
Do	.000367	.000467	.000700	.000767	.001033	.001133	.001167	.012067	.01800	.03306	.06040
Radial, muzzle end	.000400	.000567	.000767	.000900	.001133	.001233	.001267	.008433	.01286	.02420	.04467

The breech-cup forging was made from part of a 25-inch square ingot, about 50 inches high, and was afterwards annealed. The physical qualities, as determined by the Midvale Steel Company, were: Tensile strength, 73,500 pounds per square inch; elongation after rupture, 27.5 per cent.; contraction of area, 38 per cent.

The muzzle collar forging was made from the same ingot as the breech-cup, but was not annealed. The physical qualities, as determined by the Midvale Steel Company, were: Tensile strength, 77,570 pounds per square inch; elongation after rupture, 13.5 per cent.; contraction of area, 13.2 per cent.

ROLLED HOOPS FOR A 12-INCH MUZZLE-LOADING RIFLED MORTAR.

The dimensions of these hoops were as follows, viz:

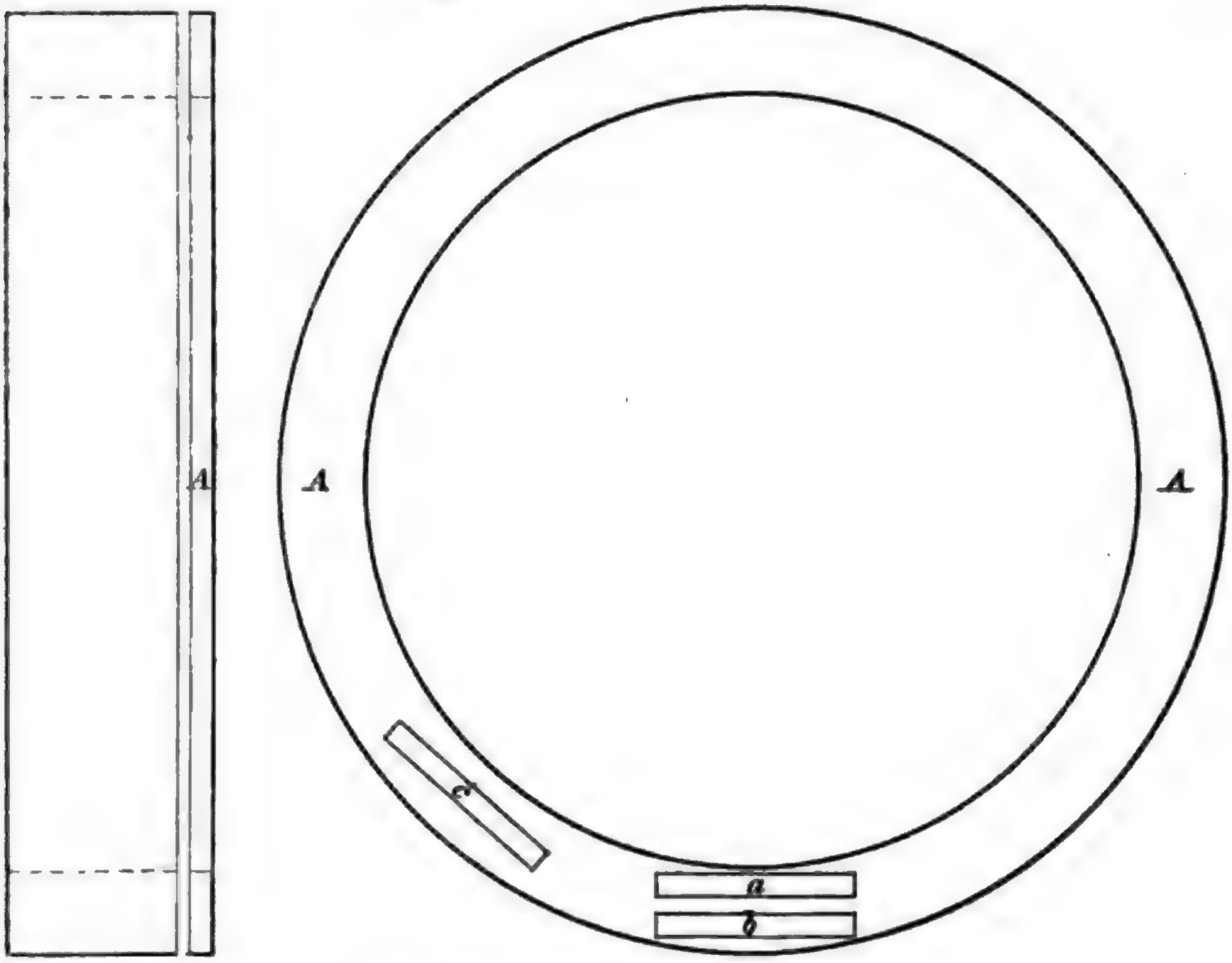
Number of hoops.	Exterior diameter.	Interior diameter.	Length.
	Inches.	*Inches.*	*Inches.*
4	41.5	35.9	8.31
2	41.5	35.9	9.00
1	37.1	31.0	9.00
5	35.9	31.0	8.50
2	35.9	31.0	9.00
1	35.9	31.0	8.75

They were required to be rough-finished, allowing ⅛ of an inch on a side over the dimensions given; to be oil-tempered and subsequently annealed; the metal to have the following physical qualities, viz: Elastic limit, 22 to 25 tons per square inch; tensile strength, 42 to 46 tons per square inch; elongation after rupture, 15 to 20 percentum; determined by the test of specimens at least 3 inches long between shoulders.

In his circular letter to the steel manufacturers of the country, dated April 3, 1883, the Chief of Ordnance stated that to obtain the physical qualities desired in steel forgings for ordnance purposes special treatment would be necessary, and expressed his opinion that the mode of treatment by annealing after oil-tempering would give a more suitable metal, one combining a high elasticity with considerable ductility, than any other mode of which the Department had information, provided the operations were attended with certainty and uniformity.

The results of the tensile and shrinkage tests of the two experimental hoops manufactured by the Midvale Steel Company, one oil-tempered and subsequently annealed, the other simply annealed, after rolling (see Appendices 41 and 42, Report of the Chief of Ordnance, 1883), seemed to warrant the belief that the opinion so expressed was correct, and these hoops, contracted for September 20, 1883; and those for an 8-inch steel breech loading rifle, contracted for about a month later, were consequently required to be oil-tempered and subsequently annealed. A lack of uniformity shown in the experimental oil-tempered hoop referred to above, was explained by the Midvale Steel Company to be probably due to a known unequal heating in the annealing after oil-tempering, which they expected to prevent in any further work by the aid of new and more suitable furnaces. The degree of uniformity attained in the manufacture of the hoops will be seen by an examination of the following tables, giving the results of the tensile tests of the metal.

Fig. 1.



A.—Ring from edge of hoop.
a.—Position of inside specimen.
b.—Position of outside specimen.
c.—Position of middle specimen.

The Midvale Steel Company's method of manufacturing large rolled gun-hoops is essentially the same, up to the point of treatment in oil as the method of manufacturing large locomotive tires. Special heats of open-hearth steel are run for the purpose, the chemical composition being as nearly like as possible. Care is taken to have the metal used free from any defects. After they have been rolled the hoops are reheated, oil-tempered, and afterwards annealed, the degree of heat in these operations depending upon the chemical composition of the metal, the results obtained in the test of a "preliminary" specimen, the size of the piece to be treated, and the physical qualities required. When the hoops have been accepted as to physical qualities, on the results of the Government tests, they are rough-finished. The Midvale Steel Company had, until they undertook the manufacture of these 12-inch mortar-hoops, rolled tires of a maximum width of only 7.5 inches. For these hoops and for the rolled hoops for an 8-inch steel breech-loading rifle a new set of rolls was made, having a height of 9.5 inches, which delivered hoops about 9.25 inches in length when cold.*

That the hoops might be used of as great length as possible in the construction of the mortar, it was decided by the Department to test only a limited number of those manufactured (those required to finish 9 inches long in the above table), these "test hoops" to be so selected by the inspector as to represent in the best possible manner all the hoops of the lot. The specimens for test were either slotted from the edge of the hoop or taken from rings of metal cut from the edge, as shown on Figure 1.

The results of the tests of the specimens made at the Watertown Arsenal are given below.†

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* Still another set of rolls for gun hoops is now being manufactured, designed to deliver hoops to finish 12 inches long. In the opinion of the company's officers this length is the greatest that their tire mill can turn out without danger of breakage.

† The hammered hoops for 8-inch steel rifle were made from the same ingots as the mortar hoops, so the results of the tests of these specimens can be compared with the results obtained in the tests of the hammered-hoop specimens.

Results of tensile tests of tangential specimens from rolled steel hoops for 12-inch muzzle-loading rifled mortar.

Specimen.		Position.*	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
From hoop marked—	Number.		Length.	Diameter.								
			In.			*Pounds.*	*Inch.*	*Pounds.*	*Inch.*	*P. ct.*		
Ax	1	Inside	6	0.564 of an inch.	0.25 of a square inch.	63, 000	. 002033	115, 200	. 13	27. 6		
Ax	2	Outside	6			50, 000	. 001883	112, 600	. 123	27. 6	7. 8552	27. 32
Ax	3	Inside	3			63, 000	. 002200	112, 000	. 183	32. 5		
Ax	4	Outside	3			60, 000	. 001867	111, 870	. 157	26. 4	7. 8551	25. 43
Ax	5	Middle	6			65, 000	. 002183	112, 080	. 1267	24. 4		
Ax	6	do	6			63, 000	. 002150	110, 800	. 1267	27. 6		
A$_1$	1	Inside	6			63, 000	. 002033	109, 000	. 165	49. 6		
A$_1$	2	Outside	6			59, 000	. 001833	106, 160	. 165	44. 4	7. 8557	23. 04
A$_1$	3	Inside	3			62, 000	. 001767	107, 240	. 203	48. 8		
A$_1$	4	Outside	3			58, 000	. 001967	105, 510	. 210	48. 6	7. 8587	23. 44
A$_1$	5	Inside	6			55, 000	. 001800	103, 400	. 162	47. 2		
A$_1$	6	Outside	6			59, 000	. 001933	104, 000	. 17	49. 6		
A$_5$	1	Inside	6			66, 000	. 002150	111, 000	. 1433	49. 6		
A$_5$	2	Outside	6			66, 000	. 002166	111, 800	. 15	36. 4	7. 8561	
A$_5$	3	Inside	3			67, 000	. 002133	118, 720	. 1066	39. 2		
A$_5$	4	Outside	3			62, 000	. 002000	116, 200	. 1733	30. 8		
A$_5$	5	Inside	6			71, 000	. 002180	119, 600	. 1250	36. 4	7. 8528	
A$_5$	6	Outside	6			68, 0 0	. 002183	119, 400	. 1267	30. 8		
A$_5$	7	Inside	3			68, 000	. 002133	112, 000	. 18	44. 4		
A$_5$	8	Outside	3			65, 000	. 002100	113, 200	. 1333	15. 2		
Bx	1	Inside	6			68, 000	. 002033	117, 600	. 089	33. 6		
Bx	2	Outside	6			65, 000	. 002067	112, 000	. 153	39. 2	7. 8543	26. 67
Bx	3	Inside	3			71, 000	. 002467	116, 460	. 16	35. 4		
Bx	4	Outside	3			64, 000	. 002000	112, 650	. 16	29. 3	7. 8556	26. 99
Bx	5	Middle	6			57, 000	. 001867	108, 440	. 105	33. 6		
Bx	6	do	6			67, 000	. 002250	114, 000	. 128	30. 8		
B$_1$	1	Inside	6			72, 000	. 002167	117, 410	. 145	43. 7		
B$_1$	2	Outside	6			72, 000	. 002250	117, 810	. 133	43. 7		
B$_1$	3	Inside	3			73, 000	. 002333	117, 440	. 17	47. 2		
B$_1$	4	Outside	3			73, 000	. 002100	118, 000	. 173	43. 7		
Bex	1	Inside	6			62, 000	. 001867	113, 000	. 135	33. 6		
Bex	2	Outside	6			54, 000	. 001600	106, 720	. 14	36. 4		
Bex	3	Inside	6			64, 000	. 002000	115, 000	. 143	33. 6	7. 8539	
Bex	4	Outside	6			59, 000	. 001967	110, 320	. 14	33. 6	7. 8558	
Bex	†5	Middle	6			50, 000	. 001567	102, 000	. 173	36. 4	7. 8548	
Bex	†6	do	6			50, 000	. 001467	105, 200	. 167	36. 4	7. 8524	
Bex	‡11	Inside	6			58, 000	. 001950	108, 900	. 132	36. 4		
Bex	‡12	Outside	6			54, 000	. 001750	106, 440	. 163	36 4		
Bex	‡13	Middle	6			51, 000	. 001650	102, 000	. 17	39. 2		

Results of tensile tests of tangential specimens, &c.—Continued.

Specimen.		Elongations per inch of length caused by the undermentioned loads.										
From hoop marked—	Number.	15,000 pounds per square inch.	30,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	58,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.	70,000 pounds per square inch.	75,000 pounds per square inch.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Ax	1	.000383	.000867	.001150	.001367	.001500	.001683	.001783	.001867	.002233	.004017	.0075
Ax	2	.000450	.000833	.001217	.001350	.001533	.001733	.001767	.002000	.002550	.005333	.0092
Ax	3	.000467	.000833	.001167	.001333	.001500	.001667	.001767	.001933	.002850	.006267	.0108
Ax	4	.000133	.000733	.001067	.001267	.001433	.001600	.001667	.001867	.002767	.006333	.0116
Ax	5	.000383	.000867	.001200	.001350	.001533	.001700	.001733	.001867	.002183	.004017	.0080
Ax	6	.000367	.000850	.001183	.001350	.001500	.001700	.001733	.001933	.002483	.005350	.0091
A_1	1	.000433	.000867	.001233	.001367	.001533	.001700	.001717	.001900	.003033	.007350	.0132
A_1	2	.000433	.000833	.001150	.001317	.001483	.001667	.001683	.001950	.006117	.010350	.0150
A_1	3	.000300	.000733	.001000	.001200	.001333	.001533	.001633	.001700	.003300	.007967	.0125
A_1	4	.000533	.000933	.001267	.001400	.001600	.001767	.001833	.002267	.006467	.010600	.0158
A_1	5	.000502	.000967	.001317	.001450	.001633	.001800	.001900	.003867	.007900	.012000	.0165
A_1	6	.000500	.000950	001250	.001417	.001567	.001733	.001850	.002017	.006167	.010667	.0152
A_5	1	.000467	.000800	.001230	001400	.001550	.001750	.001783	.001917	.002117	.002983	.0072
A_5	2	..	.000833	.001083	.	.001500	....	....	.001833	.002083	.004500	.0084
A_5	3	.000400	.000833	.001200	001367	.001500	.001733	.001767	.001900	.002067	.002400	.0043
A_5	4	.000367	.000833	.001167	.001333	.001533	.001767	.001800	.001933	.002233	.004200	.0076
A_5	5	.000433	.000833	.001133	.001283	.001467	.001616	.001650	.001767	.001933	.002150	.0032
A_5	6	.000433	.000933	.001233	.001417	001567	.001700	.001733	.001867	.002033	.002450	.0050
A_5	7	.000400	.000800	.001133	.001300	.001433	.001600	.001667	.001767	.002000	.002600	.0066
A_5	8	.000433	.000867	.001133	.001367	.001500	.001700	.001733	.001900	.002100	.003767	.0078
Bx	1	.000333	.000817	.001100	.001217	.001417	.001583	.001600	.001750	.001933	.002183	.0029
Bx	2	.000367	.000867	.001183	.001333	.001517	.001683	.001717	.001883	.002067	.002950	.0073
Bx	3	.000567	.001067	.001333	.001567	.001767	.001833	.001883	.002100	.002200	.002433	.0037
Bx	4	.000333	.000667	.001000	.001267	.001333	.001400	.001533	.001667	.002333	.005000	.0090
Bx	5	.000400	.000833	.001183	.001333	.001533	.001733	.001800	.002243	.003833	.007583	.0117
Bx	6	.000450	.000900	.001233	.001383	.001550	.001733	.001787	.001917	.002100	.002700	.0055
B_1	1	.000383	.000833	.001117	.001233	.001417	.001583	.001600	.001717	.001917	.002083	.0042
B_1	2	.000417	.000867	.001183	.001317	.001483	.001650	.001683	.001800	.002000	.002167	.0043
B_1	3	.000333	.000867	.001167	.001300	.001433	.001667	.001667	.001800	.002000	.002200	.0040
B_1	4	.000300	.000700	.000967	.001233	.001333	.001467	.001500	.001633	.001800	.002000	.0043
Bex	1	.000367	.000833	.001167	.001300	.001467	.001617	.001667	.001767	.002467	.005517	.0094
Bex	2	.000383	.000817	.001133	.001267	.001433	.001667	......	.004483	.007838	.011533	.0159
Bex	3	.000417	.000850	.001167	.001333	.001500	.001683	.001700	.001833	.002083	.003650	.0072
Bex	4	.000400	.000800	.001217	.001383	.001550	.001750	.001817	.002050	.003317	.006817	.0103
Bex	†5	.000417	.000850	.001167	.001333	.001567	.004983	....	.008650	.011867	.016133	.0210
Bex	†6	.000333	.000750	.001100	.001250	.001467	.003233	....	.006283	.009133	.013350	.0179
Bex	‡11	.000467	.000933	.001267	.001467	.001600	.001767	.001850	.002283	.006267	.008333	.0129
Bex	‡12	.000450	.000933	.001217	.001400	.001600	.001817	.001900	.004400	.007533	.011300	.0148
Bex	‡13	.000417	.000867	.001200	.001350	.001583	.005083	.005717	.008633	.011950	.016367	.0209

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* As to thickness of hoop, *i. e.*, whether taken from near *inside* or *outside* circumference or at *middle* of thickness. The axes of all the specimens, except where noted, were about three-fourths of an inch from the face of the hoop.

† From the second ring of metal cut from this hoop; axes about 1¾ inches from inside and outside surfaces and 2 inches from one face.

‡ From the third ring of metal cut from this hoop; axes about 1¾ inches from inside and outside surfaces and about 4½ inches from either face.

Results of compression tests of tangential specimens from rolled steel hoops for 12-inch muzzle-loading rifled mortar.

Specimen.		Position.	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.
From hoop marked—	Number.		Length.	Diameter.			
			Inches.			*Pounds*	*Inch.*
Ax	7	Middle	12	1 129 inches.	1 square inch.	58,000	.001870
A_8	9	do	12			65,000	.002140
A_8	10	do	12			63,000	.002110
Bx	7	do	12			55,000	.001770
Bex	14	Outside	9			60,000	....

Specimen.		Compression per inch of length caused by the undermentioned loads.								
From hoop marked—	Number.	15,000 pounds per square inch.	30,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	58,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Ax	7	.000450	.000930	.001260	.001440	.001600	.001770	.001820	.001990	.002720
A_8	9	.000480	.000950	.001270	.001420	.001610	.001780	.001820	.001960	.002140
A_8	10	.000440	.000960	.001280	.001450	.001630	.001800	.001830	.001980	.002300
Bx	7	.000440	.000930	.001250	.001430	.001590	.001770	.001830	.002130	.003770
Bex	14	......	....	....	....	....	......	......	....	....

HAMMERED RINGS FOR A WIRE-WRAPPED TUBE FOR 12-INCH BREECH-LOADING RIFLE.

These rings, three in number, were 25.75 inches exterior diameter, and 19.75 inches interior diameter, one being 5.75 inches long and each of the others 1.25 inches long, rough-finished dimensions. One hammered ring, 9.75 inches long, was made from part of a 15-inch square ingot, oil-tempered and annealed, and cut up for the three hoops. No tensile tests of the metal were made. The ingot was of a heat of metal from which several gun-hoops had been made, and a tensile test, by the Midvale Steel Company, of a specimen cut from a hoop taken from next to this one, in the same ingot, and similarly treated, showed: Tensile strength, 97,000 pounds per square inch; elongation after rupture, 24 per cent.; contraction of area, 49 per cent. It is believed the metal in the hoops would show, in tensile tests, about the standard qualities required for gun-hoops.

HAMMERED RINGS FOR REPAIR OF THE 6-INCH HASKELL MULTI-CHARGE GUN.

These rings were required to be delivered rough forged, to finish at least 16 inches long (17 inches if possible) and $2\frac{1}{4}$ inches thick, the interior diameter of the largest to taper from $23\frac{3}{8}$ inches at one end to 22.1 inches at the other end; the interior diameter of the second to taper from $20\frac{7}{16}$ inches at one end to $19\frac{1}{4}$ inches at the other end, and the interior diameter of the third to taper from $17\frac{7}{16}$ inches at one end to $16\frac{1}{4}$ inches at the other end. The rings were forged very nearly to the shape and dimensions required, with the usual allowance of metal for finishing, and were oil-tempered and afterward annealed.

No tensile tests of the metal were made, but from the test of a specimen cut from a ring made from one of the ingots from which these rings were made, and similarly treated, it is believed the metal is of the standard qualities required for gun-hoops.

ROLLED AND HAMMERED HOOPS FOR AN 8-INCH STEEL BREECH-LOADING RIFLE.

The dimensions of these hoops were as follows, viz:

Number of hoops.	Exterior diameter.	Interior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
8	26. 3	22. 0	8. 25	Rolled.
4	26. 3	22. 0	9. 00	Do.
1	30. 0	22. 0	8. 50	Do.
4	31. 5	26. 3	8. 25	Do.
1	31. 5	26. 3	8. 50	Do.
1	31. 5	26. 3	8. 00	Do.
4	31. 5	26. 3	9. 00	Do.
1	25. 8	19. 8	9. 84	Hammered.
2	25. 2	19. 8	9. 84	Do.
1	25. 2	19. 8	9. 00	Do.
3	19. 8	15. 75	7. 84	Do.
1	19. 8	15. 75	9. 00	Do.
4	20. 5	15. 75	8. 25	Do.
1	20. 75	15. 75	9. 00	Do.

The hoops to be rough finished, allowing one-eighth of an inch on a side over these dimensions; the physical qualities to be the same as required for the 12-inch mortar hoops, and the same plan to be followed in testing.

The rolled hoops were made in the same manner as those for the 12-inch mortar. The manufacture of the hammered hoops differs from that of the rolled hoops in that the operation of rolling is omitted and the required dimensions are obtained as nearly as possible under the hammer. The hoops are oil-tempered after they come from the hammer, and from this point the operations of manufacture follow as for rolled hoops.

Below are given the results of the tests, with the United States testing machine at Watertown Arsenal, of the specimens from these 8-inch rifle hoops.

Results of tensile tests of tangential specimens from hammered and rolled steel hoops for 8-inch breech-loading rifle.

SPECIMENS FROM HAMMERED HOOPS.

Specimen— From hoop marked—	Specimen— Number.	Position.*	Dimensions. Length.	Dimensions. Diameter.	Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
			In.			*Pounds.*	*Inch.*	*Pounds.*	*Inch.*	*P. ct.*		
C_4	1	Inside	6	0.564 of an inch.	0.25 of a sq. in.	67,000	.002100	117,400	.123	39.2	7.8576	24.12
C_4	2	Outside	3			65,000	.002167	116,560	.157	33.6	....	.....
C_4	3	Middle	6			66,000	.002066	115,160	.137	39.2	....	.....
Cx	1	Inside	6			63,000	.002050	115,880	.100	36.4	7.8616	23.70
Cx	2	Outside	3			65,000	.002033	114,480	.167	39.2	....	.....
Cx	3	Middle	6			59,000	.001916	109,800	.120	36.4	....	.....
Dx	3	....do	6			60,000	.001883	111,600	.143	39.2	7.8549	26.51
Dx	4	....do	6			64,000	.002116	113,440	.118	36.4	....	.....

SPECIMENS FROM ROLLED HOOPS

From hoop marked—	Number.	Position.*	Length.	Diameter.	Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
Ax	1	Inside	6	0.564 of an inch.	0.25 of a square inch.	62,000	.001783	107,280	.1317	41.9	....	.....
Ax	2	Outside	6			62,000	.002017	107,200	.1667	41.9	....	.....
Ax	3	Inside	3			65,000	.002067	105,200	.1933	52.2	....	.....
Ax	4	Outside	3			66,000	.001967	109,240	.1767	44.6	....	.....
Ax	5	Middle	6			62,000	.002050	105,160	.1533	54.6	....	.....
Ax	6	..do	6			59,000	.001950	105,460	.145	44.6	....	.....
A_8	5	....do	6			63,000	.002117	105,120	.1433	47.2	....	.....
A_8	6	....do	6			63,000	.002083	108,640	.1317	41.9	....	.....
A_6	1	Inside	6			64,000	.002017	109,280	.140	52.4	7.8631	23.30
A_6	2	Outside	6			67,000	.002133	1 8,000	.153	56.8	....	.....
Anf	1	Inside	6			60,000	.001850	108,400	.150	39.2	7.8598	25.13
An	2	Outside	3			63,000	.002100	108,600	.160	39.2	....	.....
An	3	Inside	6			59,000	.001916	108,600	.115	27.6	....	.....
An	4	Outside	3			56,000	.001766	74,000	.010	0.	....	.....
An	5	Middle	6			62,000	.002133	104,600	.0583	8.4	....	.....
An	6	do	6			58,000	.001983	107,600	.115	30.6	....	.....
Bx	1	Inside	6			58,000	.001833	103,280	.160	39.2	....	.....
Bx	2	Outside	6			55,000	.001700	101,840	.1567	39.2	....	.....
Bx	3	Inside	3			61,000	.001933	104,360	.1867	39.2	....	.....
Bx	4	Outside	3			60,000	.001933	104,000	.1867	39.2	....	.....
B_2	1	Inside	6			65,000	.002000	114,000	.103	33.6	7.8615	24.26
B_2	2	Outside	6			61,000	.001967	112,000	.147	27.6	....	.....
B_3	1	Inside	6			67,000	.002150	113,600	.118	39.2	7.8564	26.83
B_3	2	Outside	6			62,000	.002016	110,000	.110	39.2	....	.....
B_3	3	Inside	3			65,000	.002166	108,920	.167	39.2	....	.....
B_3	4	Outside	3			70,000	.002300	111,160	.150	39.2	....	.....
B_4	1	Inside	6			59,000	.001917	102,880	.140	47.2	....	.....
B_4	2	Outside	6			59,000	.001850	104,440	.1317	39.2	....	.....
B_4	3	Inside	3			57,000	.001700	102,960	.1933	41.9	....	.....
B_4	4	Outside	3			54,000	.001733	100,000	.1767	44.6	....	.....

Results of tensile tests of tangential specimens, &c.—Continued.

SPECIMENS FROM HAMMERED HOOPS—Continued.

Specimen—		Elongations per inch of length caused by the undermentioned loads.										
From hoop marked—	Number.	15,000 pounds per square inch.	30,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	56,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.	70,000 pounds per square inch.	75,000 pounds per square inch.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch*	*Inch.*	*Inch.*
C_4	1	.000467	.000900	.001233	.001350	.001517	.001683	.001733	.001867	.002033	.002633	.0060
C_4	2	.000433	.000930	.001200	.001366	.001533	.001667	.001733	.001900	.002167	.004833	.0062
C_4	3	.000333	.000816	.001150	.001300	.001466	.001633	.001658	.001816	.002016	.005000	.0075
Cx.....	1	.000500	.001017	.001267	.001417	.001617	.001750	.001800	.001950	.002183	.003400	.0065
Cx.....	2	.000433	.000933	.001233	.001367	.001467	.001633	.001733	.001833	.002033	.004433	.0081
Cx	3	.000466	.000900	.001250	.001400	.001583	.001766	.001816	.002050	.004150	.007633	.0125
Dx ..	3	.000416	.000866	.001200	.001366	.001550	.001700	.001750	.001883	.003700	.006083	.0108
Dx	4	.000433	.000916	.001250	.001400	.001583	.001750	.001816	.001950	.002216	.005116	.0087

SPECIMENS FROM ROLLED HOOPS.

Ax	1	.000417	.000833	.001130	.001300	.001467	.001617	.001633	.001750	.002150	.005100	.0096
Ax	2	.000450	.000900	.001220	.001367	.001550	.001733	.001767	.001933	.002850	.006967	.0097
Ax	3	.000367	.000833	.001067	.001333	.001500	.001667	.001700	.001833	.002067	.006300	.0110
Ax	4	.000333	.000767	.001033	.001200	.001367	.001500	.001533	.001700	.001933	.004167	.0083
Ax	5	.000467	.000950	.001300	.001467	.001633	.001800	.001817	.001983	.002483	.007450	.0117
Ax	6	.000467	.000950	.001283	.001433	.001617	.001767	.001850	.002017	.004717	.008800	.0128
A_5	5	.000467	.000900	.001250	.001417	.001600	.001783	.001817	.001967	.002433	.006650	.0112
A_5	6	.000450	.000933	.001250	.001417	.001583	.001767	.001800	.002000	.002233	.004950	.0090
A_6	1	.000467	.000933	.001233	.001383	.001533	.001700	.001733	.001883	.002067	.002600	.0074
A_6	2	.000433	.000917	.001233	.001400	.001517	.001683	.001750	.001867	.002050	.004000	.0091
A_{11}	1	.000416	.000866	.001200	.001333	.001500	.001683	.001767	.001850	.002400	.005500	.0097
A_{11}	2	.000366	.000883	.001166	.001300	.001433	.001633	.001733	.001900	.002433	.005633	.0097
A_{11}	3	.000416	.000883	.001286	.001383	.001566	.001733	.001800	.002030	.003166	.006000	.0101
A_{11}	4	.000366	.000866	.001200	.001333	.001533	.001700	.001766	.002200	.004566	.008766	......
A_{11}	5	.000433	.000900	.001250	.001400	.001583	.001767	.001800	.002017	.002733	.006367	.0105
A_{11}	6	.000467	.000950	.001283	.001433	.001617	.001800	.001883	.002150	.003800	.008000	.0115
Bx.....	1	.000417	.000850	.001167	.001333	.001517	.001717	.001750	.002100	.005270	.009850	.0167
Bx.....	2	.000383	.000817	.001150	.001333	.001517	.001700	.001767	.002867	.007033	.011480	.0165
Bx.....	3	.000367	.000833	.001167	.001333	.001533	.001700	.001733	.001900	.003133	.008300	.0122
Bx.....	4	.000367	.000833	.001200	.001333	.001533	.001667	.001733	.001933	.003767	.008467	.0131
B_2	1	.000400	.000900	.001200	.001300	.001500	.001650	.001683	.001817	.002000	.002717	.0046
B_2	2	.000400	.000900	.001267	.001350	.001500	.001683	.001733	.001900	.002450	.005117	.0090
B_3	1	.000433	.000900	.001233	.001383	.001550	.001700	.001750	.001833	.002083	.002383	.0040
B_3	2	.000416	.000900	.001250	.001400	.001566	.001733	.001766	.001933	.002266	.003666	.0088
B_3	3	.000333	.000866	.001200	.001333	.001500	.001700	.001766	.001900	.002166	.003800	.0079
B_3	4	.000333	.000833	.001167	.001300	.001467	.001633	.001666	.001833	.002000	.002300	.0044
B_4	1	.000450	.000900	.001250	.001417	.001600	.001750	.001833	.002000	.003283	.008033	.0139
B_4	2	.000367	.000833	.001183	.001333	.001500	.001667	.001733	.001917	.002833	.007333	.0118
B_4	3	.000367	.000767	.001100	.001300	.001433	.001633	.001667	.002233	.005433	.010267	.0145
B_4	4	.000400	.000867	.001200	.001333	.001567	.001867	.002000	.003433	.007533	.012233	.0172

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* As to thickness of hoop, i. e., whether taken from near *inside* or *outside* circumference or at middle of thickness. The axes of all the specimens were about three-fourths of an inch from the face of the hoop.

† This hoop rejected.

Results of compression tests of tangential specimens from hammered and rolled steel hoops for 8-inch breech-loading rifle.

SPECIMENS FROM HAMMERED HOOPS.

Specimen—		Position.	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.
From hoop marked—	Number.		Length.	Diameter.			
			Inches			*Pounds.*	*Inch.*
C_4	4	Middle	9	1.132 inches.	1.007 square inches	60,000	.002100
Cx	4	do	9			60,000	.001967

Specimen—		Compression per inch of length caused by the undermentioned loads.								
From hoop marked—	Number.	15,000 pounds per square inch.	30,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	58,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
C_4	4	.000467	.000983	.001367	.001533	.001750	.001900	.001933	.002100	.002500
Cx	4	.000400	.000883	.001250	.001417	.001617	.001800	.001817	.001967	.006050

SPECIMENS FROM ROLLED HOOPS.

Specimen—		Position.	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.
From hoop marked—	Number.		Length.	Diameter.			
			Inches.			*Pounds.*	*Inch.*
A_6	3	Middle	9	1.129 inches.	1.0 square inch.	65,000	.002050
A_6	4	do	9			63,000	.002000
B_2	3	do	9			61,000	.001900
B_2	4	do	9			58,000*	.001833*

*Elastic limit not well defined; probable elastic limit given.

Specimen—		Compression per inch of length caused by the undermentioned loads.								
From hoop marked—	Number.	15,000 pounds per square inch.	30,000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	58,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.
		Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
A_6	3	.000400	.000867	.001167	.001333	.001517	.001683	.001700	.001850	.002050
A_6	4	.000433	.000867	.001283	.001383	.001533	.001700	.001717	.001867	.002100
B_2	3	.000400	.000883	.001200	.001383	.001533	.001700	.001733	.001867	.002267
B_2	4	.000433	.000950	.001233	.001433	.001600	.001733	.001767	.001917	.002533

FORGINGS FOR THE BREECH MECHANISM OF 12-INCH, 10-INCH, AND 8-INCH BREECH-LOADING RIFLES AND CASTING FOR 10-INCH RIFLE.

The rough finished dimensions of these forgings were as follows, viz

Nature of piece.	Exterior diameter.	Interior diameter.	Length.	Remarks.
	Inches.	*Inches.*	*Inches.*	
12-inch breech blocks	15.75	3.25	22.0	
10-inch breech blocks	13.75	2.50	20.25	
8-inch breech block	11.5	2.0	21.75	With projections.
12-inch spindles	14.0		4.0	Exterior surfaces joined by bevel.
	4.75		26.0	
10-inch spindle	11.5		3.5	Do.
	4.0		24.0	
8-inch spindle	10.0		3.5	Do.
	3.25		21.75	
12-inch levers	15.0		1.38	With projection.
10-inch lever	13.0		1.25	Do.
Hammered ring	41.0	28.38	1.25	
Do	36.25	31.25	1.25	
Sleeve casting	39.25	35.73	27.0	

The physical qualities of the metal to be as follows:

For breech blocks and spindles:		
Elastic limit per square inch	tons..	22 to 25
Tensile strength per square inch	do...	45 to 50
Elongation after rupture	per cent..	12
For levers:		
Tensile strength per square inch	tons..	36
Elongation after rupture	per cent..	20
For rings:		
Elastic limit per square inch	tons..	25 ± 2
Tensile strength per square inch	do...	45 to 50
Elongation after rupture	per cent..	15 to 20
For the sleeve casting:		
Elastic limit per square inch	tons..	18 to 20
Tensile strength per square inch	do...	40 to 45
Elongation after rupture	per cent..	over 10

Work on this contract had at the end of the fiscal year proceeded as far as the forging, oil-tempering, and annealing of the breech blocks, spindles, and levers, and casting the sleeve.

The breech blocks and spindles were forged from 30-inch square ingots; before oil-tempering, the breech blocks were rough bored. The levers were forged from a 15-inch square ingot.

The results obtained in tensile tests of specimens from three of the breech block and one of the spindle forgings are given below:

Results of tensile tests of tangential specimens from forgings for breech blocks and spindle.

Specimen from—	* Position.	Dimensions.		Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Specific gravity.	Hardness.
		Length.	Diameter.								
		In.			*Lbs.*	*Inch.*	*Lbs.*	*Inch.*	*P.c.*		
10-inch breech block.	Middle point of axis 3 inches from axis of block.	3	0.564 of an inch.	0.25 of a square inch.	50,000	.001700	98,840	.1707	33.5	7.8625	21.17
Do	Near exterior	3			57,000	.001967	101,360	.2033	41.9	......	.....
12-inch breech block.	Middle point of axis 3 inches from axis of block.	3			48,000	.001467	94,720	.1733	36.4	......	.....
Do	Near exterior	3			57,000	.001600	100,800	.150	33.5	......	.....
Do	Middle point of axis 3 inches from axis of block.	3			49,000	.001567	97,000	.1567	39.2	7.8610	19.93
Do	Near exterior	3			58,000	.001800	102,560	.1867	41.9	......	.....
12-inch spindle.	From head, middle point of axis 3 inches from axis of block.	3			52,000	.001667	102,600	.0967	15.0	7.8568	20.82
Do	From head, near exterior.	3			50,000	.001467	96,240	.210	41.9	......	.....

Specimen from—	Elongations per inch of length caused by the undermentioned loads.									
	15,000 pounds per square inch.	30,000 pounds per square inch.	35 000 pounds per square inch.	40,000 pounds per square inch.	45,000 pounds per square inch.	48,000 pounds per square inch.	50,000 pounds per square inch.	55,000 pounds per square inch.	60,000 pounds per square inch.	65,000 pounds per square inch.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
10-inch breech block	.000600	.000967	.001133	.001300	.001433	.001600	.001700	.002400	.005833	.0102
Do	.000400	.000933	.001067	.001233	.001400	.001500	.001567	.001800	.002333	.0054
12-inch breech block	.000300	.000833	.001000	.001133	.001367	.001467	.001767	.003333	.008400	.0124
Do	.000067	.000567	.000800	.000933	.001100	.001200	.001300	.001533	.001933	.0050
Do	.000433	.000933	.001100	.001233	.001400	.001533	.001667	.004667	.008500	.0125
Do	.000433	.000933	.001067	.001200	.001333	.001433	.001500	.001667	.001967	.0036
12-inch spindle	.000400	.000933	.001067	.001233	.001400	.001500	.001600	.002067	.004100	.0076
Do	.000333	.000733	.000933	.001100	.001267	.001367	.001467	.002267	.006300	.0109

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* The specimens were cut from disks (slices) about 1½ inches thick, taken from an end of the forgings.

On the contracts for rolled hoops for 12-inch breech-loading rifle and for rings, forgings, and casting for 10-inch wire-wound steel rifle no work had been done up to the end of the fiscal year.

The size of the rolled hoops for 12 inch rifle made special preparations for their manufacture necessary. The time has been occupied in making these preparations.

The press of other work prevented anything being done under the contract for parts of 10-inch wire-wound steel rifle.

Below will be found a table showing the effect of annealing or of oil-tempering and subsequent annealing on several steel pieces manufactured by the Midvale Steel Company for the Department. The results given are from tests made by the company. It is to be regretted that their testing machine does not determine the elastic limit. The company expect during the present summer to put up a Fairbank's testing machine of 150,000 pounds capacity, which will determine this physical property.

Nature of piece.	Treatment.	Results of test before treatment.			Results of test after treatment.		
		Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.
		Pounds.	*Inch.*	*Per ct.*	*Pounds.*	*Inch.*	*Per ct.*
Tube for 3.2-inch rifle	Annealed	100,500	.105	15.6	87,700	.160	26.0
Tube for 8-inch converted rifle.	do	80,400	.090	8.0	71,500	.255	39.7
Jacket for 3.2-inch rifle	Oil tempered and annealed.	95,068	.125	13.0	102,900	.145	22.0
Hammered hoop for 8-inch rifle	do	88,900	.205	33.0	106,600	.175	35.0
Do	do	94,100	.195	32.0	102,000	.205	47.0
Rolled hoop for 8-inch rifle.	do	89,500	.215	31.0	100,200	.175	35.0
Rolled hoop for 12-inch mortar	do	97,500	.210	28.7	107,000	.180	40.0
Rolled hoop for 8-inch rifle	do	89,000	.185	27.0	107,000	.190	39.0
Hammered hoop for 8-inch rifle	do	97,000	.220	28.0	106,000	.200	41.0
Breech block for 12-inch rifle	do	86,132	.115	12.0	97,720	.150	31.0
Breech block for 10-inch rifle	do	84,880	.240	41.0	94,880	.200	41.0
Lever for 12-inch rifle	do	88,400	.200	37.0	86,920	.240	48.0
Spindle for 12-inch rifle	do	103,813	.055	5.2	97,500	.175	29.0
Do	do	95,820	.130	13.0	94,700	.190	40.0
Rolled hoop for 10-inch rifle	do	85,780	.220	34.0	101,160	.190	34.0

In January, 1884, parts of the rings of metal cut from 12-inch mortar hoops A_5 and Bex were straightened and tested.

The object of this experimental work was: (1) To compare the results obtained in the test of these straightened specimens with those from the tangential specimens tested for the approval of the physical qualities of the metal; and (2) if it was found that the operation of straightening was so performed as to give reliable results, to determine the question of the advisability of using large straightened specimens to determine the physical qualities of the metal instead of the short tangential specimens.

By straightening a portion of a ring of metal from a hoop, cut off before rough finishing, one dimension of the cross-section of the specimen could be made the same as the thickness of the finished hoop, and test of the specimen would thus show the true physical qualities of the whole hoop better than the short tangential specimens, provided the straightening process did not injure or change the metal in any way.

The pieces of rings were straightened slowly under the hammer by pressure only and at as light a heat as possible. After cutting tangential test specimens from the first and second rings taken from hoop Bex, 42.4 inches exterior diameter and 35.1 inches interior diameter, there remained four pieces, two from each ring, each about 50 inches long and 1.5 inches thick. These pieces were heated lightly and placed under the 9-ton hammer several times; the pressure had little or no straightening effect, however, until they were heated to redness as seen in the shop building. As it was thought possible that the temper of the metal might have been drawn somewhat in this operation one of the pieces from each ring was retempered and annealed just sufficiently to restore the supposed loss of temper. These pieces were used for extension specimens, being finished and tested at Watertown Arsenal.

After cutting tangential specimens from the ring taken from hoop A_5 there remained a piece about 16 inches long and 1.2 inches thick; this was straightened in the same manner as the pieces from hoop Bex and not retempered. It was used for two compression specimens, being finished and tested at Watertown Arsenal. A summary of the results obtained in the test of these straightened specimens is given below. The results were very unsatisfactory, being very low, and the bars not of uniform quality throughout, as shown by the records of the several gauges. The metal had evidently been injured or changed in straightening or by the heat employed for that operation.

Results of tests of specimens from straightened rings taken from rolled steel hoops for 12-inch mortar.

TENSION TESTS.

Specimen from hoop marked—	Position.	Dimensions. Length.	Dimensions. Cross-section.	Sectional area.	Elastic limit per square inch of original section.	Elongation per inch under strain at elastic limit.
		Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Inch.*
Bex	From first ring cut from hoop	30	2.8 x 1.25	3.5	45,000 49,000 47,000	.001490 .001620 .001560
Bex	do	30	2.8 x 1.225	3.43	40,000 41,400 40,000	.001337 .001327 .001327
Bex	From second ring cut from hoop.	30	2.8 x 1.438	4.03	47,000 50,000 50,000	.001563 .001810 .001680
Bex	do	30	2.8 x 1.479	4.14	41,000 42,000 42,000	.001370 .001430 .001413

Specimen from hoop marked—	Position.	Tensile strength per square inch of original section.	Elongation per inch after rupture.	Reduction in area after rupture.	Remarks.
		Pounds.	*Inch.*	*Per cent.*	
Bex	From first ring cut from hoop.	87,170	.173	47.5	On section A.* On section B. On section C.
Bex	do	76,000	.156	49.4	On section A.* On section B. On section C. Retempered.
Bex	From second ring cut from hoop.	91,070	.1653	42.4	On section A.* On section B. On section C.
Bex	do	79,180	.1423	49.3	On section A.* On section B. On section C. Retempered.

*Three micrometers were used for measuring the elongations. The micrometer on section A covered the whole length of stem of specimen, 30 inches, along the center line of the bar. The micrometer on section B covered 10 inches length, and that on section C covered 15 inches length. Sections B and C were taken along the same side of the bar and 0.2 of an inch from the edge.

COMPRESSION TESTS.

Specimen— From hoop marked—	Specimen— Number.	Position.	Dimensions. Length.	Dimensions. Diameter.	Sectional area.	Elastic limit per square inch of original section.	Compression per inch under strain at elastic limit.
			Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Inch.*
A_8	11	Inside	12	1.019	0.817	56,000	.001870
A_8	12	Outside	12	1.129	1.000	60,000	.001850

APPENDIX 30.

REPORT ON THE MANUFACTURE OF STEEL FOR GUN CONSTRUCTION BY THE OTIS IRON AND STEEL COMPANY.

BY WILLIAM M. MEDCALFE, LIEUTENANT OF ORDNANCE.

(1 plate.)

Under contract of December 18, 1883, the company was called upon to furnish 12 hammered steel bars 4.1 inches square and 24 feet long, one hammered bar of same cross-section 12 feet long, and 375 rolled steel billets 2 inches square and weighing 80 pounds each.

Up to June 30, 1884, 14 bars and 402 billets were manufactured and tested. Of these 11 bars and 311 billets have been accepted.

MANUFACTURE.

Open-hearth steel was required, and four heats, averaging 32,000 pounds each, were made to fill the contract. The charge for each weighed 36,500 pounds, 15 per cent. being allowed for wastage. No scrap was used, pig iron, low in phosphorous, and wrought-iron blooms composing the charge.

The pig iron was first introduced and brought to a molten state. The blooms, raised to a red heat in mufflers situated in rear of the Siemens furnace, were then added to the bath. About five or ten minutes before tapping the spiegel in lumps was thrown in, having been previously brought to a white heat.

The composition of each charge was, roughly speaking, 82 per cent. of blooms, 15 per cent. of pig, and 3 per cent. of spiegeleisen, the latter containing 40 per cent. of Mn.

The blooms used were partly Otis blooms and partly so-called charcoal blooms from Chautauqua, Lake Champlain. One heat made entirely with the former gave decidedly better results in the test of transverse specimens, a fact probably due to the low percentage of phosphorous contained in these blooms. It has been therefore decided by the superintendent to use hereafter only iron of the company's manufacture for steel to fill the Government contracts now pending.

The metal was cast in iron molds, both closed and open, arranged in groups of four and six about a central riser a little taller than the molds. The ingots averaged 2,900 pounds and were 14 inches square at the bottom, tapering slightly towards the upper end.

In every case before a heat was selected preliminary tests were made similar to those required under the contract.

In the manufacture of the billets the ingots, heated to a yellow heat, were rolled down in the blooming mill to 8 inches square. The upper half of the ingot was then cut off and the lower half returned to the mill and rolled down to 5 inches square, requiring in all 17 passes. This bar was cut up into lengths sufficient to make three 2-inch billets. The pieces of each ingot were then replaced in the furnace and kept together, the piece nearest the top of the ingot being marked. When again raised to a yellow heat they were rolled into bars 2 inches square, which were cut up into 80-pound billets. All billets from any one ingot were marked with the same number, the top billet being set aside and afterwards specially marked so as to be distinguished from the others. A 6-inch test piece was cut off above the upper end of each top billet.

For the hammered bars the ingots were rolled down to 7 inches square, and the upper half cut off. The lower half, after having been cleaned, was formed into a 24-foot bar, 4.1 inches square, under a 3-ton steam-helve hammer. A test piece 6 inches long was taken beyond the upper end of each bar and marked with the number of the bar.

TESTING.

The different heats used were analyzed for combined carbon only. The results were as follows:

	Per cent
Heat No. 1	0.31
Heat No. 2	0.32
Heat No. 3	0.31
Heat No. 4	0.32

The physical tests for the first eight ingots rolled into billets and for two of the hammered bars were made at the Washington navy-yard. The remainder of the tests were made on the Olsen testing machine at the Otis works by Mr. George Bartol and the inspector.

For each bar four tests were prepared, central and outside, longitudinal and central, and outside transverse specimens. The diameter of their least section was 0.5 inch, and the distance between measuring points 2 inches, a seven-eighths-inch thread being cut on the ends.

For each ingot rolled into billets two tests were prepared, a longitudinal specimen of the same dimensions as for bars, and a diagonally transverse specimen 0.3 inch in diameter, and 1.2 inches between measuring points.

The specimens were annealed in batches of twenty-five or thirty, according to a method proposed by Dr. W. E. Woodbridge.

The annealing box was a strong wrought-iron pipe, plugged at the lower end, 6 inches in diameter and 18 inches long; a steel cover screwed on and closed the upper end. The packing consisted of cast iron turnings, mixed with 10 per cent. of finely divided iron oxide, the proportion of the latter being afterwards increased to 20 per cent. to prevent carbonization. The mixture was first heated red hot and allowed to cool in the box. The specimens, after having been examined as to accuracy of dimensions, were bound into bundles and packed in the mixture. Two heat tests were at first used, one being a piece of copper with sharp edges, the other an alloy of five parts copper and one tin. These tests were placed in boxes made of inch piping closed with a screw plug. The box containing the copper was placed near the exterior and that containing the alloy in the center of the annealing tube. The temperature of annealing was so regulated that the bronze heat test was melted, the copper remaining unmelted and coming out with sharp edges. The difference between the melting points of these substances was, however, so great that at the suggestion of Dr. Woodbridge a third heat test was used, composed of fifteen parts of copper and one of tin, and the temperature kept between the melting points of the two alloys.

The annealing was done in a low regenerator gas furnace, and generally took a little over an hour, as the box was heated up very gradually. At a bright red heat it was withdrawn, imbedded in pulverized slaked lime and left to cool slowly.

In annealing the third batch the temperature was purposely carried higher than in the case of first two lots, although still kept well within the melting point of copper. On pulling these tests it became apparent that their physical properties had been injured. The fracture, instead of being silvery, was semi-crystalline and crystalline, and the ultimate extension and contraction of area fell below what was to be expected.

Additional tests were made of the same steel, the third heat test being used, and the temperature kept down to what it had been in the first two annealings. A comparison of the results showed that the higher temperature had materially impaired the extensibility and contractibility of the specimens without noticeably affecting their tenacity.

Specimens annealed in the manner described come from the box looking bright and untarnished.

Experiments were made to determine the amount and depth of carbonization experienced by the tests while in the annealing box.

Two pieces were annealed in the usual manner. Off of the first piece turnings were taken from the outside and from near the center, and analyzed with the following results: Combined carbon, outside, 0.49; center, .036. From the second turnings were taken as from the first, and also at about one-sixteenth of an inch below the surface, to determine the depth at which carbonization took place. The analysis gave: Combined carbon, outside, 0.46; intermediate, 0.38; center, 0.37; showing that the carbon had not penetrated to any extent into the interior of the test piece. The length of time during which the specimen is exposed to the carbonizing action undoubtedly determines largely the depth in question.

The percentage of iron oxide was then increased to 20, and similar experiments made with a view to lessening the carbonizing action, but without satisfactory results. The effect, however, upon the physical properties of the test is probably insignificant, owing to the slight depth to which the action extends. In one case, where 20 per cent. of iron oxide was used, a noticeable decarbonizing action was shown by the analysis to have taken place.

Combined carbon, outside, 0.32 and 0.33; center, 0.40 and 0.41.

The results of all the tests made at the Otis works have been tabulated and hereto annexed. The measurements were made with micrometer gauges reading to .001 of an inch.

The holders of the specimens, constructed according to the suggestions of Dr. Woodbridge, proved to be very serviceable. The two center wedges which in the Olsen machine clasp the end of the test, were removed and replaced by a single wedge. Through the latter a hole was bored for the passage of the arm of the holder. An accurately turned socket, sunk in the upper surface of the wedge, received a hemispherical head on the end of the arm of the holder. With this arrangement the adjustment of the axis of the specimen in the line of greatest strain was easy and perfect, as the head of the holder turned readily in its socket when any cross-strain was brought to bear upon the specimen.

A number of thin transverse plates were prepared for the purpose of examining the continuity of the steel. These plates were generally taken from billets whose test pieces showed flaws or some peculiarity. One side was smooth finished, and examined under a glass for defects of continuity, and afterwards bulged by hammering or on the testing machine, to open or extend such defects, and the surface again examined. Most of these plates were sent to the ordnance office for examination. Those tested at the Otis works showed considerable variations. In all, bulging developed defects, but their size, number, appearance, and distribution varied greatly. If a flaw of any size existed in the plate it soon opened at that point, and cracks radiating from it showed up. In other cases the metal stretched equally throughout the plate, the small openings noticed being evenly distributed over the whole bulged surface.

The bars and billets were also inspected for dimensions, cracks, flaws, or laps, and such as were found unsatisfactory rejected.

CAST-STEEL CYLINDER.

In conformity with the instructions contained in a letter from the Chief of Ordnance, dated February 14, 1884, the Otis Iron and Steel Company made for test a trial cylinder of cast steel 24 inches in diameter and 5 feet long. It was made of open hearth steel, from a heat of 31,000 pounds, and cast in a sand mold with a sinking head equal to the length of the cylinder. The mold was lined with thin sheet iron to preserve it from injury, the metal entering at the upper .end of the mold cavity. The resulting ingot was 10 feet long, 25 inches in diameter, and weighed in the neighborhood of 17,000 pounds.

A mean of seven analyses made of borings, taken from different parts of the cylinder, was as follows: Combined carbon, 0.55 per cent.; silicon, 0.13 per cent.; phosphorus, 0.029 per cent.; manganese, 0.96 per cent.

The ingot was left in the pit to cool slowly for two days, and afterwards removed to the machine-shop, turned down to 24 inches, and the upper half cut off. A 6-inch hole was then bored through the center, when the cylinder was ready for annealing. It was placed in a regenerative gas-heating furnace with doors at both ends. A piece of iron pipe was inserted in the central hole at each end and projected some inches beyond the doors, which were bricked up about the pipes. An inch steam-pipe was conducted to one of these pipes, by means of which a jet of steam could be thrown in and a strong current of cold air produced through the bore of the cylinder. The temperature was raised gradually, the flame being directed alternately above and below the cylinder to insure even heating throughout. When at a yellow heat the gas was shut off and the cylinder allowed to cool in the furnace over night, the blast being left in action. This operation was repeated three times.

The cylinder was then removed to the lathe and a ring 1.25 inches thick detached from each end, from which tangential and radial specimens were afterwards taken. Another ring, 2.5 inches thick, was cut from the lower end, to be tested for initial tension. The remainder of the cylinder then received two through cuts lengthwise, removing two slabs, 3.25 inches thick, on opposite sides of the bore. From these slabs 16 specimen pieces were taken, each piece being stamped with a number and the lower end marked

In all 28 specimens were taken from the cylinder, as follows:

	No. of specimens.	Size square.	Length.
		Inches.	*Inches.*
For tangential extension	6	1.25	9.0
For radial extension	6	1.25	9.0
For longitudinal extension	6	1.25	9.0
For radial compression	2	1.25	9.0
For longitudinal compression	2	1.25	9.0
For transverse resistance	2	1.25	22.0
For radial bursting	2	3.45	5.0
For longitudinal bursting	2	3.45	5.0

These specimens, with the initial tension ring, were shipped to the commanding officer of Watertown Arsenal for test.

The success attained at these works under the able management of Mr. S. T. Wellman, the superintendent, in the manufacture of wrought-iron blooms, using rotary puddlers, deserves remark. As it is the only plant of its kind in operation in this country, and, with the exception of that at Le Creusot, about the same in size, the only one in the world, the following brief description of the process (for the details of which I am indebted to Mr. George Goetz, in charge of the bloomery) may be of interest to the department:

The plant consists of a Siemens regenerative gas furnace for melting the pig; two gas producers; two rotary puddlers of the modified Dank pattern, and a 10-ton steam hammer.

The Siemens furnace has a capacity of 30,000 pounds molten pig. In construction it differs from the ordinary pattern in having the heating chambers placed in pairs on either side of the main supporting pillars, through which pass the flues for the entrance of the gas and air into the furnace and for the exit of the products of combustion; the advantage of this arrangement being that the particles of slag carried into the flues by the draught fall into pockets at the bottom of the flues, and not, as is the case with furnaces in which the flues open directly into these chambers, into the chambers themselves. The bottom of each pocket is an inclined surface, allowing the slag to run out at an opening in the lower end.

The bed of the furnace, instead of resting upon the brick arches of the chambers below, is supported by iron trusses which run over to and rest upon the main pillars, thus relieving the arches from a heavy load. A considerable space is left free between the bottom of the bosh and the brick-work below. Although this construction would seem to have the disadvantage of preventing the furnace bed from heating up rapidly, it is not found to be so in practice. In the melting-house, where the furnaces are of the same kind, a heat of 38,000 pounds of steel has been made in four and a half hours.

The producer situated immediately in rear of the furnace, is of novel pattern. Its exterior form is that of a circular cylinder 14 feet high. An outer casing of boiler-plates, riveted together, contains the refractory lining, which is about 9 inches thick. The interior section is a quadrilateral, bounded by curved lines, the spaces between the casing and lining being filled with common brick. About 2 feet from the bottom is the grate, above this the interior widens up to half its height, and then contracts from a diameter of 6 feet 8 inches at the widest part to 4 feet 8 inches at the top. A large body of fuel is thus secured in that portion of the producer in which deoxidation is to take place.

The draft is produced by a steam blast playing into two 6-inch air-pipes which enter the furnace on either side and below the grate. The amount of steam to be used is a matter of importance, as an excess gives an inferior quality of gas, while a deficiency impairs the draft. For a producer of the size described a steam jet of five thirty-seconds of an inch diameter is used, with a pressure of one-fourth of an inch of water.

The resulting gas contains more combustible gases than are obtained from the ordinary producer, viz: 4 per cent. CO_2, 27 to 29 per cent. CO, 11 to 13 per cent. of H, and about 5 per cent. of hydro carbons ($C_2 H_4$). The high percentage of H, resulting from the decomposition of the steam is noticeable.

The charge for the melter is made up of different kinds of pig-iron, so that the molten mixture will contain the proper amount of silicon and manganese, which is from 0.8 to 1 per cent. of Si. and about 1 per cent. of Mn.

This refined pig is tapped off as required into a ladle holding 2,500 to 3,000 pounds which runs on a track in front of the puddlers.

The puddlers are modified Danks, having a drum 8 feet 6 inches long from ring to ring, and a diameter of 6 feet 6 inches. The initial lining is a mixture of 50 per cent. of ground hematite ore and 50 per cent. of slaked lime. Upon this cracked ore is placed and melted, an operation taking about two hours. Into this liquid bath lumps of ore about the size of a man's head are thrown and become cemented on the lining, acting afterwards as a rake to stir the charge. A fix lasts on an average five heats.

The pig-iron is poured on a hot bottom, the drum making about ten revolutions per minute. Pig of the above composition will boil in about five minutes and come to nature in ten or fifteen minutes. It is then shaped with tools or "balled up," and is ready to be drawn and put under the hammer.

The slag produced is very basic, and as a consequence the amount of phosphorus in these blooms is remarkably low, an average of the analyses for one week being 0.007 per cent. If any sulphur is present in the pig, about 0.50 per cent. of the charge is limestone, which removes it very effectually, forming Ca S.

The percentage of silicon in the pig is highly important, as too little gives blooms which will not hammer, and too much is very destructive to the bottoms. The production is large, No. 1 drum averaging during one week while the inspector was at the works, 30,000 pounds of hammered blooms per day of ten hours.

Table of tests.

[Tests marked with a * were annealed at a higher temperature than the others, and additional tests afterwards made to determine the effect of this change in temperature of annealing upon their physical properties.]

Number of heat.	Number of ingot stamped on the test.	Nature of test.	Description.	Diameter of minimum cross-section.	Tenacity per square inch of original minimum cross-section.	Reduction of original cross-section at rupture.	Ultimate elongation.	Portion of ingot from which test piece was taken.	Remarks.
				Inches.	*Pounds.*	*Per ct.*	*Per ct.*		
2	1	L.	Billet.	.500	78,520	55.6	31.3	From billets, other than top billet, selected at random from the pile; tests 1-8 inclusive, are additional tests, these ingots having been previously tested at the Washington navy-yard.	
2	1	T.	..do...	.301	77,324	26.8	22.9		
2	2	L.	..do...	.500	80,153	56.1	31.9		
2	2	T.	..do...	.300	....	25.4	15.9		Test piece broken before record of tenacity was obtained.
2		L.	..do...	.503	80,502	55.3	30.65		
2	3	T.	..do...	.300	75,634	22.5	15.5		
2	4	L.	..do...	.500	82,092	54.1	30.65		
2	4	T.	..do...	.300	78,169	21.1	16.0		
2	5	L.	..do...	.498	80,256	54.4	31,4		
2	5	T.	..do...	.299	28,285	....	....		Flaw extending across fracture. All billets from this ingot rejected.
2	6	L.	..do...	500	82,143	54.1	31.85		Top billet rejected.
2	6	T.	..do...	.297	74,203	26.1	15.08		
2	*6	L.	..do...	.457	82,012	54.3	30.5		
2	6	T.	..do...	.297	74,991	21.7	12 33		
2	7	L.	..do...	.500	82,041	53.1	29.85		
2	7	T.	..do...	.298	76,285	25.7	15.00		
2	8	L.	..do...	.501	81,370	54.3	30.2		All billets of this ingot rejected.
2	8	T.	..do...	.300	42,535	....	....		Flaw of bright color .05 inch in width extending clear across fracture.

Table of tests—Continued.

Number of heat.	Number of ingot stamped on the test.	Nature of test.	Description.	Diameter of minimum cross-section.	Tenacity per square inch of original minimum cross-section.	Reduction of original cross-section at rupture.	Ultimate elongation.	Portion of ingot from which test piece was taken.	Remarks.
				Inches.	*Pounds.*	*Per ct.*	*Per ct.*		
2	9	L.	Billet.	.300	83,380	57.7	31.67	From above the top end of top billet of each ingot.	Top billet reje't'd
2	9	T.	..do...	.293	74,776	14.9	10.83		Turned by mistake to dimensions transverse test piece.
2	10	L.	..do...	.301	80,845	54.9	30.91		
2	10	T.	..do...	.296	72,464	20.3	10.67		
3	11	L.	..do...	.500	78,723	54.1	31.3		
3	11	T.	..do...	.295	75,440	20.6	14.42		
3	12	L.*	..do...	.503	77,940	47.2	28.3		
3	12	T.	..do...	.300	74,790	19.7	15.08		
3	13	L.	..do...	.500	78,980	55.1	31.15		
3	13	T.	..do...	.298	73,570	20.0	16.0		
3	14	L.*	..do...	.504	77,400	48.0	29.4		
3	14	T.	..do...	.288	75,690	26.1	19.42		
3	15	L.	..do...	.497	80,155	52.6	30.85		Top billet rejected.
3	15	T.	..do...	.297	72,320	14.5	10.0		
3	16	L.	..do...	.496	80,311	54.9	31.4		Top billet rejected.
3	16	T.	..do...	.297	75,360	15.9	12.08		
3	17	L.	..do...	.499	79,745	56.1	31.05		
3	17	T.*	..do...	.299	75,000	14.8	12.83		
3	18	L.*	..do...	.504	78,600	45.5	27.6		
3	18	T.	..do...	.297	74,638	18.8	13.67		
4	19	L.	..do...	.493	79,633	55.5	31.9		
4	19	T.*	..do...	.295	74,412	17.6	14.25		
4	20	L.	..do...	.496	80,777	55.4	32.2	From above the top end of top billet of each ingot.	
4	20	T.	..do...	.298	77,143	21.4	15.25		
4	21	L.*	..do...	.504	79,600	46.0	27.95		
4	21	T.	..do...	.293	77,015	20.9	15.83		
3	22	L.	..do...	.500	78,470	57.1	32.85		
3	22	T.	..do...	.298	73,714	17.1	12.75		
4	23	L.	..do...	.499	80,408	55.1	31.45		Top billet rejected.
4	23	T.	..do...	.299	74,143	17.1	10.08		
4	24	L.	..do...	.496	83,212	52.85	30.15		Top billet rejected.
4	24	T.	..do...	.299	75,286	15.7	9.9		
4	25	L.	..do...	.498	78,718	53.3	31.25		
4	25	T.	..do...	.299	78,285	20.0	13.25		
4	26	L.	..do...	.499	80,255	53.6	30.05		
4	26	T.	..do...	.289	75,303	22.7	14.42		

ADDITIONAL BILLET TESTS.

Number of heat.	Number of ingot stamped on the test.	Nature of test.	Description.	Diameter of minimum cross-section.	Tenacity per square inch of original minimum cross-section.	Reduction of original cross-section at rupture.	Ultimate elongation.	Portion of ingot from which test piece was taken.	Remarks.
3	14	L.	Billet	.495	77,340	55.73	32.35	From top billet of each ingot.	
3	17	T.	..do...	.298	73,171	24.28	14.5		
3	18	L.	..do...	.497	78,300	53.09	31.65		
4	19	T.	..do...	.290	73,480	19.7	14.25		
4	21	L.	..do...	.498	78,720	52.82	31.5		
2	9	L.	..do...	.497	80,930	55.15	31.45	From billet other than top billet selected at random from the pile.	
2	9	T.	..do...	.297	75,800	18.41	12.92		
3	15	T.	..do...	.299	71,430	21.43	15.58		
3	16	T.	..do...	.299	78,000	21.43	16.17		
4	23	T.	..do...	.266	73,390	23.21	17.25		
4	24	T.	..do...	.300	74,220	23.94	18.23		

Table of tests—Continued.

ADDITIONAL BILLET TESTS—Continued.

Number of heat.	Number of ingot stamped on the test.	Nature of test.	Description.	Diameter of minimum cross-section.	Tenacity per square inch of original minimum cross-section.	Reduction of original cross-section at rupture.	Ultimate elongation.	Portion of ingot from which test piece was taken	Remarks.
				Inches.	*Pounds.*	*Per ct.*	*Per ct.*		
0	5	C. L.	Bar...	....	66, 871	59. 72	37. 7	From above the top end of bar.	Tested at Washington Navy-Yard. (Rejected.) The numbers stamped on the bars run from 1 to 24, inclusive. The numbers not found in the table correspond to ingots rolled to 7 inches by 7 inches blooms, but not hammered, and of the same heat as bar No. 5, which was rejected.
0	5	O. L.	..do ...	.. ....	73, 052	55. 21	32. 95		
0	5	C. T.	..do ...	....	66, 364	28. 25	21. 05		
0	5	O. T.	..do ...	....	71, 228	18. 6	11. 8		
1	12	C. L.	..do ...	. 504	73, 450	54. 0	33. 1		
1	12	O. L.	..do ...	. 489	76, 276	54. 2	32. 65		
1	12	C. T.	..do ...	. 497	69, 587	18. 0	10. 75		Slight flaw in fracture.
1	12	O. T.	..do ...	. 500	73, 367	18. 8	12. 25		
1	13	C. L.	..do ...	. 500	75, 610	53. 6	31. 0		
1	13	O. L.	..do ...	. 499	75, 815	56. 1	30. 85		
1	13	C. T.	..do ...	. 505	73, 400	22. 0	14. 8		
1	13	O. T.	..do ...	. 497	70, 875	22. 2	11. 4		
1	14	C. L.	..do ..	....	73, 457	56. 27	31. 35		Tested at Washington navy-yard.
1	14	O. L.	..do ...	....	75, 230	58. 87	33. 60		
1	14	C. T.	..do...	....	73, 203	27. 74	17. 65	From above the top end of bar.	
1	14	O. T.	..do ...	......	77, 408	25. 01	17. 30		
1	15	C. L.	..do ...	. 502	76, 566	51. 0	30. 3		
1	15	O. L.*	..do ...	. 500	78, 877	46. 4	28. 15		
1	15	C. T.	..do ..	. 497	72, 370	20. 1	14. 5		
1	15	O. T.	..do ...	. 499	73, 670	28. 1	15. 15		
3	16	C. L.	..do ...	. 499	75, 150	52. 5	30. 95		
3	16	O. L.	. do ...	. 496	78, 190	54. 4	30. 45		
3	16	C. T.	. do ...	. 502	73, 430	21. 2	11. 5		
3	16	O. T.	..do ...	. 500	71, 070	16. 8	10. 05		
1	17	C. L.	..do ...	. 497	75, 300	51. 0	29. 85		
1	17	O. L.	..do ..	. 506	78, 010	52. 2	30. 75		
1	17	C. T.	..do ...	. 504	66, 750	12. 5	8. 65		Slight flaw extending across fracture. Rejected.
1	17	O. T.	..do ..	. 502	74, 090	22. 1	13. 95		
3	18	C. L.	..do ..	. 495	79, 270	47. 9	29. 25		
3	18	O. L.	..do ...	. 501	78, 630	49. 5	28. 75		
3	18	C. T.	..do ...	. 501	71, 218	14. 7	10. 75		
3	18	O. T.	..do ...	. 506	75, 220	20. 9	14. 65		
1	19	C. L.	. do ...	. 494	75, 090	51. 6	27. 8		
1	19	O. L.	. do ..	. 502	76, 363	52. 5	31. 85		
1	19	C. T.	. do ...	. 505	72, 400	22. 5	12. 0		
1	19	O. T.	..do...	. 503	72, 814	19. 6	13. 35		
1	20	C. L.*	..do ...	. 503	75, 678	47. 2	26. 85		
1	20	O. L.	..do ...	. 497	78, 814	52. 06	29. 05		
1	20	C. T.*	. do ...	. 498	64, 798	15. 66	8. 80		
1	20	O. T.	. do ..	. 500	73, 112	15. 8	12. 15		
1	21	C. L.	. do ...	. 493	76, 858	48. 7	29. 05		
1	21	O. L.	.do ..	. 494	76, 198	53. 1	31. 2		
1	21	C. T.	do ...	. 491	70, 635	21. 2	14. 35		
1	21	O. T.	.do...	. 501	72, 233	18. 8	11. 9		
3	22	C. L.*	..do ...	. 502	73, 687	48. 5	29. 8		
3	22	O. L.*	.do ...	. 504	76, 500	50. 0	30. 0		
3	22	C. T.*	. do....	. 495	70, 260	19. 3	13. 25		
3	22	O. T.*	..do. ..	. 497	76, 185	23. 2	15. 35		
3	23	C. L.*	do....	. 505	74, 300	48. 5	31. 15		
3	23	O. L.*	..do...	. 494	77, 500	46. 66	29. 55		
3	23	C. T.*	.do....	. 499	69, 592	17. 85	11. 25		
3	23	O. T.*	..do....	. 495	77, 135	25. 5	22. 0		
4	24	C. L.	..do ...	. 497	77, 319	53. 61	31. 6		Rejected.
4	24	O. L.	.do...	. 496	82, 950	50. 26	27. 5		
4	24	C. T.	..do ..	. 496	70, 830	13. 99	9. 9		
4	24	O. T.	..do ...	. 496	77, 460	17. 62	15. 85		

ADDITIONAL BAR TESTS.

Number of heat.	Number of ingot stamped on the test.	Nature of test.	Description.	Diameter of minimum cross-section.	Tenacity per square inch of original minimum cross-section.	Reduction of original cross-section at rupture.	Ultimate elongation.	Portion of ingot from which test piece was taken	Remarks.
1	20	C. L.	Bar..	. 496	76, 680	52. 33	31. 4	Taken above first test piece.	
1	20	C. T.	..do	. 498	69, 900	18. 46	10. 05		
1	22	C. L.	..do....	. 496	73, 210	57. 51	32. 75		
1	22	C. T.	..do ...	. 498	69, 440	22. 6	13. 05		
1	23	C. L.	. do....	. 500	74, 950	54. 08	31. 85		
1	23	C. L.	..do. .	. 497	71, 440	18. 56	13. 25		

Table of tests made after June 30, 1884, of steel furnished by the Otis Iron and Steel Company, under contract of December 18, 1883.

Number of heat.	Number of ingot from which test was taken.	Nature of test.	Description.	Diameter of least section.	Tenacity per square inch of original cross-section.	Reduction of cross-section by breaking.	Ultimate elongation.	Portion of ingot from which specimen was taken.	Remarks.
				In.	*Lbs.*	*P.ct.*	*P.ct.*		
5	27	L.	Billet	.5	75,880	48.9	30.10	Top end of top billet of each ingot.	
5	27	T.	....do	.3	70,280	25.35	19.42		
5	28	L.	....do	.5	75,520	48.45	30.15		
5	28	T.	....do	.3	71,140	31.43	24.50		
5	29	L.	....do	.5	75,690	48.71	28.75		
5	29	T.	....do	.3	70,420	32.39	23.67		
5	30	L.	....do	.5	74,130	51.02	30.85		Superficial longitudinal flaw, ½ inch long, not visible in fracture.
5	30	T.	....do	.3	70,710	28.57	21.58		
5	31	L.	....do	.5	76,530	48.47	29.80		
5	31	T.	....do	.3	71,430	31.43	22.75		
5	32	L.	....do	.5	75,000	48.45	30.25		
5	32	T.	....do	.3	70,280	32.39	20.42		
5	33	L.	....do	.5	71,900	50.26	29.75		
5	33	T.	....do	.3	70,710	20.00	15.17		
9	25	O. L.	24-foot bar	.495	79,950	50.52	28.65	Above top end of bar.	
9	25	C. L.	24-foot bar.	.496	75,080	49.74	30.60		Several small circular flaws in fracture, noticeable with glass. Rejected.
9	25	O. T.	24 foot bar	.498	73,230	18.97	12.35		
9	25	C. T.	24-foot bar	.494	68,700	16.67	10.10		Two flaws of brownish color extending clear across fracture, one smaller flaw extending partly across fracture.
9	26	O. L.	12-foot bar.	.499	78,470	48.98	27.9		Temperature of annealing in the case of specimens of bars 25 and 26 was found on examination of heat tests to have been carried a little too high, and additional tests for bar 26 were made.
9	26	C. L.	12-foot bar	.500	73,470	50.56	29.85		
9	26	O. T.	12-foot bar	.500	75,000	19.90	11.30		Flaw of greenish color extending partly across fracture.
9	26	C. T.	12-foot bar	.499	71,170	28.57	19.75		
9	26	C. L.	12-foot bar.	.498	70,970	60.51	36.20	From a piece taken some distance above top end of bar.	
9	26	O. L.	12-foot bar	.497	76,550	55.67	32.80		
9	26	C. T.	12-foot bar.	.497	70,260	17.42	16.15		Small flaw, of brownish color.
9	26	O. T.	12-foot bar.	.497	73,970	19.59	14.70		
10	27	C. L.	24-foot bar.	.499	75,510	54.08	32.40	Above top end of bar.	
10	27	O. L.	24-foot bar.	.499	79,850	51.02	30.35		
10	27	C. T.	24-foot bar.	.498	73,690	28.72	20.80		
10	27	O. T.	24-foot bar.	.499	76,220	19.39	13.35		Crystalline spot in fracture.

Table of tests made of steel furnished by the Otis Iron and Steel Company, under contract of June 30, 1884, for 45,000 of rolled billets.

[Tests marked with a * were annealed in the same batch with those of bars 25 and 26, the temperature being somewhat high. Certain additional tests were therefore made to ascertain the effect of this increase of temperature.]

7	34	L.*	Billet	.496	72,330	51.81	32.1	Above top end of top billet of each ingot.	Top billet rejected and additional tests made.
7	34	T.*	....do	.298	68,860	28.57	18.25		
7	35	L.*	....do	.500	73,620	51.02	31.05		Additional tests made.
7	35	T.*	....do	.299	74,000	34.29	22.83		
7	36	L.*	....do	.500	75,200	48.47	29.55		Do.
7	36	T.*	....do	.299	71,800	32.86	24.92		
7	37	L.*	....do	.500	75,970	47.45	30.00		Do.
7	37	T.*	....do	.299	70,710	22.86	14.42		

Table of tests made of steel furnished by the Otis Iron and Steel Company, &c.—Continued.

Number of heat.	Number of ingot from which test was taken.	Nature of test.	Description.	Diameter of least section.	Tenacity per square inch of original cross-section.	Reduction of cross-section by breaking.	Ultimate elongation.	Portion of ingot from which specimen was taken.	Remarks.
				In.	*Lbs.*	*P. ct.*	*P. ct.*		
7	38	L.*	Billet	.502	75, 860	46. 97	29. 45	Above top end of top billet of each ingot.	Additional tests made.
7	38	T.*	do	.299	74, 290	31 43	23. 0		
7	39	L.*	do	.498	74, 870	47. 69	29. 35		Do.
7	39	T.*	do	.298	71, 286	25. 71	18. 50		
7	40	L.*	do	.496	75, 130	48. 19	30. 25		Do.
7	40	T.*	do	.299	70, 860	24. 29	17. 58		
6	41	L.*	do	.499	78, 980	46. 43	26. 40		Top billet rejected and additional tests made.
6	41	T.*	do	.299	73, 570	18. 57	12. 25		
6	42	L.*	do	.499	79, 590	44. 39	26. 65	Above top end of top billet of each ingot.	Top billet rejected and additional tests made.
6	42	T.*	do	.298	73, 570	21. 43	1[illegible]. 25		
6	43	L.*	do	.498	80, 050	44. 10	26. 60		Do.
6	43	T.*	do	.299	71, 430	20. 00	12. 25		
6	44	L.*	do	.495	76, 870	46. 82	26. 70		Additional tests made.
6	44	T.*	do	.299	73, 710	24. 29	18 58		
6	45	L.*	do	.496	77, 100	47. 69	28 10		Do.
6	45	T.*	do	.299	74, 140	25. 71	18. 50		
6	46	L.*	do	.498	78, 620	47. 18	27. [illegible]		Do.
6	46	T.*	do	.300	72, 820	23. 93	18. 58		
6	47	L.*	do	.498	79, 380	46. 66	27. 75		Top billet rejected and additional tests made.
6	47	T.*	do	.299	75, 430	15. 71	13. 92		
6	48	L.*	do	.498	78, 770	48 72	30. 45		Do.
6	48	T.*	do	.298	74, 860	18. 57	13. 50		
8	49	L.	do	.500	86, 790	52. 55	27. 80		Do.
8	49	T.	do	.300	80, 280	40. 85	19. 33		
8	50	L.	do	.501	84, 670	53 3	28 75		Do.
8	50	T.	do	.298	82, 710	34. 29	17. 25		
8	51	L.	do	.496	83, 420	52. 85	28. 40		Do.
8	51	T.	do	.298	80, 710	40. 00	27. 17		
8	52	L.	do	.499	83, 930	53 06	27. 65		Do.
8	52	T.	do	.298	82, 570	37. 14	19 50		
8	53	L.	do	.501	86, 190	50. 76	28. 35		Do.
8	53	T.	do	.299	82, 430	22. 86	15. 42		
8	54	L.	do	.496	76, 424	54. 92	31. 15		
8	54	T.	do	.300	78, 600	25. 35	15. 92		
8	55	L.	do	.497	84, 590	52. 06	27. 75		Top billet rejected and additional tests made.
8	55	T.	do	.295	81, 470	36. 76	19. 00		
8	56	L.	do	.499	81, 840	52. 55	29 30		
8	56	T.	do	.296	79, 710	24 64	18. 17		
8	57	L.	do	.494	76, 770	54. 69	31. 05		
8	57	T.	do	.299	74, 570	37. 14	20. 83		
8	58	L.	do	.498	82, 970	52. 31	29. 85		
8	58	T.	do	.299	78, 710	27. 14	16. 85		
8	59	L.	do	.496	76, 680	54. 40	28. 60		These two tests were annealed in different lots, which probably accounts for the tenacity longitudinally being much lower than transversely. Top billet rejected and additional tests made.
8	59	T.	do	.294	79, 410	39. 71	19. 58		
8	60	L.	do	.495	79, 580	55. 73	30. 00		
8	60	T.	do	.298	72, 430	24. 29	19. 92		
8	61	L.	do	.498	75, 230	60. 00	33. 80		
8	61	T.	do	.299	74, 570	25. 71	17. 25		
7	62	L.	do	.498	70, 974	58. 97	33. 70		
7	62	T.	do	.299	71, 000	35. 71	22. 25		
7	63	L.	do	.497	72, 990	61. 89	37. 45		
7	63	T.	do	.296	70, 150	40. 58	26. 25		
7	64	L.	do	.498	78, 050	55. 38	32. 05		
7	64	T.	do	.298	71, 290	40. 00	20. 33		
7	65	L.	do	.497	69, 123	61. 34	34. 75		Top billet rejected and additional tests made.
7	65	T.	do	.298	70, 000	38. 57	27. 75		
7	66	L.	do	.499	72, 240	60. 20	28. 40		Do. Small circular flaw in fracture.
7	66	T.	do	.296	72, 320	36. 23	22. 83		
7	67	L.	do	.498	76, 050	55. 90	31. 70		
7	67	T.	do	.299	75, 710	24. 29	16. 58		

Table of tests made of steel furnished by the Otis Iron and Steel Company, &c.—**Continued.**

Number of heat.	Number of ingot from which test was taken.	Nature of test.	Description.	Diameter of least section.	Tenacity per square inch of original cross-section.	Reduction of cross-section by breaking.	Ultimate elongation.	Portion of ingot from which specimen was taken.	Remarks.
				In.	*Lbs.*	*P. ct.*	*P. ct.*		
6	68	L.	Billet	.494	76,823	56.77	31.50	Above top end of top billet of each ingot.	These tests annealed in different lots.
6	68	T.	do	.297	77,000	34.78	17.17		
6	69	L.	do	.499	73,980	58.16	31.75		Do.
6	69	T.	do	.298	75,140	37.14	20.00		
6	70	L.	do	.499	76,530	58.16	30.15		
6	70	T.	do	.298	75,570	35.71	18.92		
6	71	L.	do	.501	74,670	57.85	30.50		Top billet rejected and additional tests made.
6	71	T.	do	.295	71,620	17.65	15.58		
6	72	L.	do	.497	75,610	55.67	26.00		Do.
6	72	T.	do	.299	72,430	27.14	20.42		
6	73	L.	do	.496	79,020	55.44	30.85		
6	73	T.	do	.300	71,830	23.94	13.92		Very fine flaw of whitish color across fracture.
9	74	L.	do	.497	76,030	59.80	30.95		
9	74	T.	do	.300	73,240	26.76	18.58		
9	75	L.	do	.495	75,360	60.41	33.70		
9	75	T.	do	.300	71,830	25.35	16.33		
9	76	L.	do	.497	74,740	61.34	33.95		
9	76	T.	do	.299	71,430	24.29	14.08		
9	77	L.	do	.496	74,510	59.07	29.85		
9	77	T.	do	.296	74,200	23.19	15.58		
9	78	L.	do	.492	72,790	61.05	33.20		
9	78	T.	do	.299	72,430	31.43	19.08		
9	79	L.	do	.497	75,520	59.79	32.20		
9	79	T.	do	.296	70,870	31.88	19.83		
9	80	L.	do	.498	74,770	58.97	31.55		
9	80	T.	do	.298	71,142	30.00	19.33		
9	81	L.	do	.499	74,081	60.20	31.35		
9	81	T.	do	.298	70,290	40.00	27.00		
9	82	L.	do	.499	74,081	59.18	31.85		These tests annealed in different lots.
9	82	T.	do	.299	75,140	30.00	17.58		
9	83	L.	do	.499	74,440	59.69	32.35		Top billet rejected and additional tests made.
9	83	T.	do	.300	69,440	23.94	14.83		

Additional tests made August 26, 1884.*

7	34	L.	Billet	.493	81,361	52.36	29.75	From a billet of each ingot, other than the top billet, and selected at random from the pile.	All billets from ingot 34 finally rejected.
7	34	T.	do	.298	72,000	18.57	11.83		
6	41	L.	do	.499	78,880	56.12	31.50		Retested.
6	41	T.	do	.298	78,140	25.71	18.83		
6	42	L.	do	.499	81,990	53.06	29.50		Retested and finally rejected.
6	42	T.	do	.300	77,320	26.76	16.42		
6	43	L.	do	.498	80,871	54.36	31.65		All billets from ingot 43 finally rejected.
6	43	T.	do	.297	70,870	14.49	7.92		
6	47	L.	do	.498	82,102	51.28	29.70		Retested and finally rejected.
6	47	T.	do	.295	80,150	22.06	17.92		
6	48	L.	do	.493	79,950	54.45	30.05		Retested.
6	48	T.	do	.295	76,430	29.41	19.83		
7	65	L.	do	.495	77,500	52.60	32.00		Do.
7	65	T.	do	.298	72,710	34.29	21.58		
6	71	L.	do	.499	81,890	51.53	29.75		Do.
6	71	T.	do	.298	72,000	25.71	13.67		
6	72	L.	do	.500	82,653	53.06	30.15		Do.
6	72	T.	do	.299	76,430	30.00	18.50		
9	83	L.	Billet	.500	82,194	55.10	30.10	....	Retested.
9	83	T.	do	.299	76,140	25.71	14.75	....	

---

*These tests of ten ingots had to be repeated, except in the case of Nos. 34 and 43, owing to change in instructions directing manner of selecting specimens for additional tests.

Additional tests made in September, 1884.

Number of heat.	Number of ingot from which test was taken.	Nature of test.	Description.	Diameter of least section.	Tenacity per square inch of original cross-section.	Reduction of cross-section by breaking.	Ultimate elongation.	Portion of ingot from which specimen was taken.	Remarks.
				In.	*Lbs.*	*P. ct.*	*P. ct.*		
7	36	L.	Billet	.498	75,230	51.28	29.95	From top end of top billet of each ingot.	Top billet rejected and bottom of top billet tested. See below.
7	36	T.	....do	.296	69,560	31.88	20.92		
7	37	L.	....do	.499	73,622	53.57	32.25		Do.
7	37	T.	....do	.298	69,560	30.00	18.42		
7	38	L.	....do	.496	74,710	50.26	31.25		
7	38	T.	....do	.299	71,000	35.71	26.35		
7	39	L.	....do	.499	74,340	53.06	32.35		Top billet rejected and bottom of top billet tested.
7	39	T.	....do	.297	68,550	30.44	19.25		
7	40	L.	....do	.496	74,870	51.30	30.55		Do.
7	40	T.	....do	.292	68,960	25.37	16.83		
6	41	L.	....do	.495	79,427	51.56	30.60	From bottom of top billet of each ingot.	Flaw of brownish color extending across fracture of transverse test. Top billet rejected.
6	41	T.	....do	.300	71,410	21.13	13.93		
6	42	L.	....do	.498	77,590	49.74	30.20		All billets from ingot No. 42 rejected.
6	42	T.	....do	.298	71,430	24.29	19.33		
6	44	L.	....do	.499	77,760	54.08	31.80	From top end of top billet of each ingot.	
6	44	T.	....do	.298	71,860	25.71	15.83		
6	45	L.	....do	.496	76,170	52.85	32.90		
6	45	T.	....do	.299	72,570	27.14	22.67		
6	46	L.	....do	.497	76,550	54.12	32.50		
6	46	T.	....do	.295	72,060	36.76	22.08		
6	47	L.	....do	.499	75,820	54.59	33.10	From bottom of top billet of each ingot.	Crystalline spot in fracture. All billets from ingot No. 47 rejected.
6	47	T.	....do	.300	74,510	12.67	14.50		
6	48	L.	....do	.499	77,400	52.04	31.75		Top billet rejected.
6	48	T.	....do	.299	72,710	21.43	12.67		
8	49	L.	....do	.499	79,900	54.08	32.40		Do.
8	49	T.	....do	.297	79,200	36.23	20.00		
8	50	L.	....do	.498	80,150	53.85	32.30		Do.
8	50	T.	....do	.298	76,860	35.71	20.83		
8	51	L.	....do	.496	78,240	54.40	32.95		Do.
8	51	T.	....do	.300	77,040	35.21	22.25		
8	52	L.	....do	.498	78,460	52.31	32.50		Do.
8	52	T.	....do	.297	78,260	33.33	18.08		
8	53	L.	....do	.498	82,050	48.72	30.70		All billets from ingot No. 53 rejected.
8	53	T.	....do	.295	78,090	27.94	20.17		
8	55	L.	....do	.499	81,880	52.55	31.05		Top billet rejected.
8	55	T.	....do	.299	76,710	32.85	21.67		
8	59	L.	....do	.499	80,920	50.00	30.85		Do.
8	59	T.	....do	.299	78,000	34.29	20.58		
7	65	L.	....do	.499	73,520	52.55	32.50		Do.
7	65	T.	....do	.298	71,710	34.29	26.83		
7	66	L.	....do	.498	74,360	50.26	31.80		Do.
7	66	T.	....do	.300	70,420	32.40	23.92		
6	71	L.	....do	.499	74,490	55.61	33.95		Do.
6	71	T.	....do	.299	71,860	25.71	17.75		
6	72	L.	....do	.499	80,000	51.53	31.15		Do.
6	72	T.	....do	.293	74,180	28.36	19.92		
9	83	L.	....do	.497	76,850	56.70	33.00		Do.
9	83	T.	....do	.300	72,110	28.17	19.08		
7	36	L.	....do	.497	75,360	53.09	32.50		
7	36	T.	....do	.299	70,570	25.71	24.25		
7	37	L.	....do	.499	74,800	53.06	32.15		All billets from ingot No. 37 rejected.
7	37	T.	....do	.296	69,280	21.74	15.00		
7	39	L.	....do	.497	75,567	51.03	32.20		
7	39	T.	....do	.300	70,000	21.13	16.83		
7	40	L.	....do	.498	74,970	52.31	32.20		All billets from ingot No. 40 rejected.
7	40	T.	....do	.300	69,010	26.76	21.08		

Original tests made September 13, 1884.

Number of heat.	Number of ingot from which test was taken.	Number of test.	Direction.	Diameter of least section.	Tenacity per square inch of original cross-section.	Reduction of cross-section by breaking.	Ultimate elongation.	Portion of ingot from which specimen was taken.	Remarks.
				In.	*Lbs*	*P. ct.*	*P. ct.*		
10	84	L.	Billet	.497	77,630	35.15	34.25	Above top end of top billet of each ingot.	
10	84	T.	do	.294	74,120	29.41	19.50		
10	85	L.	do	.498	78,460	54.36	31.90		All billets from ingot 85 rejected without further test, as sufficient billets had been accepted to fill contract.
10	85	T.	do	.299	71,570	15.71	9.92		[Two slight flaws across fracture.]
10	86	L.	do	.499	76,530	35.10	31.95		
10	86	T.	do	.299	76,570	30.00	19.08		
10	87	L.	do	.498	77,850	55.38	32.85		
10	87	T.	do	.297	71,290	23.19	13.50		
10	88	L.	do	.498	76,410	55.38	32.85		
10	88	T.	do	.299	73,860	22.86	13.92		
10	89	L.	do	.497	78,660	54.12	31.00		
10	89	T.	do	.300	74,080	23.94	15.92		
10	90	L.	do	.496	80,670	54.40	31.95		
10	90	T.	do	.300	74,370	30.99	19.58		
10	91	L.	do	.495	80,050	55.73	31.95		
10	91	T.	do	.300	75,210	21.13	16.42		

SUMMARY.

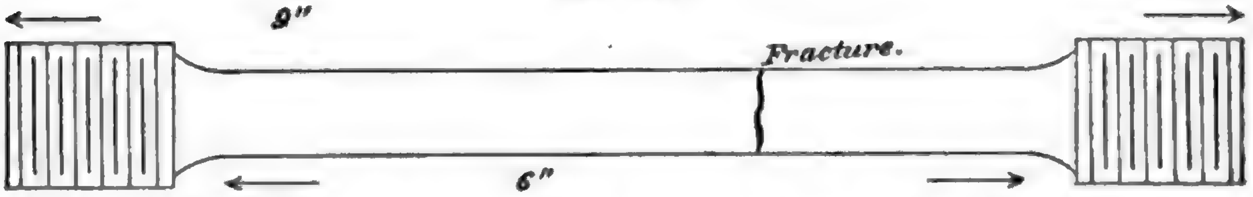
All billets rejected of ingots	34, 37, 40, 42, 43, 47, 53, 85
Top billets rejected of ingots	36, 39, 41, 48, 49, 50, 51, 52, 55, 59, 65, 66, 71, 72, 83
Number of billets manufactured to fill second contract (five heats)	716
Number of billets rejected for failure in physical tests to come up to specifications of contract	115
Number of billets rejected for cracks, laps, &c.	43
Number of billets accepted as satisfactory	558

REPORT OF MECHANICAL TESTS, MADE WITH THE UNITED STATES TESTING MACHINE, CAPACITY 800,000 POUNDS, AT WATERTOWN ARSENAL, MASSACHUSETTS, FOR THE ORDNANCE DEPARTMENT U. S. ARMY, WASHINGTON, D. C.

TESTS BY TENSION: 18 CAST-STEEL SPECIMENS FROM TRIAL CYLINDER; 1 CAST-STEEL RING FOR INITIAL TENSION; 4 CAST-STEEL CYLINDERS.

August 23, 1884.

No. 357.



[Mark on bar, 1; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
500	2,000	.000033	.000033	....	....	
750	3,000	.000083	.000050	....	....	
1,000	4,000	.000100	.000017	....	....	
1,250	5,000	.000117	.000017	0.	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
1, 500	6, 000	.000133	.000016	....	....	
1, 750	7, 000	.000167	.000034	....	....	
2, 000	8, 000	.000200	.000033	....	....	
2, 250	9, 000	.000250	.000050	....	....	
2, 500	10, 000	.000300	.000050	0.	....	
2, 750	11, 000	.000300	0.	....	....	
3, 000	12, 000	.000317	.000017	....	....	
3, 250	13, 000	.000350	.000033	....	....	
3, 500	14, 000	.000400	.000050	....	....	
3, 750	15, 000	.000433	.000033	.000000	.000000	
4, 000	16, 000	.000483	.000050	....	....	
4, 250	17, 000	.000500	.000017	....	....	
4, 500	18, 000	.000533	.000033	....	....	
4, 750	19, 000	.000550	.000017	....	....	
5, 000	20, 000	.000600	.000050	.000017	.000017	
5, 250	21, 000	.000617	.000017	....	....	
5, 500	22, 000	.000650	.000033	....	....	
5, 750	23, 000	.000683	.000033	....	....	
6, 000	24, 000	.000717	.000034	....	....	
6, 250	25, 000	.000733	.000016	.000017	0.	
6, 500	26, 000	.000800	.000067	....	....	
6, 750	27, 000	.000833	.000033	....	....	
7, 000	28, 000	.000850	.000017	....	....	
7, 250	29, 000	.000867	.000017	....	....	
7, 500	30, 000	.000950	.000083	.000050	.000033	
7, 750	31, 000	.000950	0.	....	....	
8, 000	32, 000	.000983	.000033	....	....	
8, 250	33, 000	.001050	.000067	....	....	
8, 500	34, 000	.001083	.000033	....	....	
8, 750	35, 000	.001117	.000034	.000067	.000017	
9, 000	36, 000	.001150	.000033	....	....	
9, 250	37, 000	.001200	.000050	....	....	
9, 500	38, 000	.001233	.000033	....	....	
9, 750	39, 000	.001267	.000034	....	....	Elastic limit.
10, 000	40, 000	.001617 .002883	.000350 .001266	.001567	.001550	
10, 250	41, 000	.003783	.000900	....	....	
10, 500	42, 000	.005017	.001234	....	....	
10, 750	43, 000	.005567	.000550	....	....	
11, 000	44, 000	.006383	.000816	....	....	
11, 250	45, 000	.006950	.000567	.005367	.003800	
11, 500	46, 000	.007717	.000767	....	....	
11, 750	47, 000	.008133	.000416	....	....	
12, 000	48, 000	.009200	.001067	....	....	
12, 250	49, 000	.009750	.000550	....	....	
12, 500	50, 000	.010700	.000950	.008800	.003433	Micrometer removed.
13, 000	52, 000	.0133	.0026	....	....	
13, 500	54, 000	.0150	.0017	....	....	
14, 000	56, 000	.0167	.0017	....	....	
14, 500	58, 000	.0183	.0016	....	....	
15, 000	60, 000	.0200	.0017	....	....	
15, 220	60, 880	....	....	....	....	Ultimate strength.

Fractured suddenly under the maximum load.

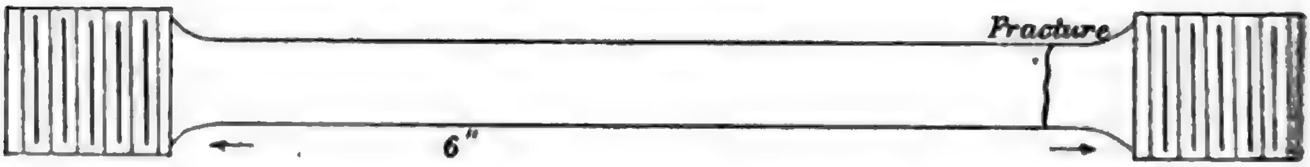
GENERAL SUMMARY.

Specific gravity		See No. 17.
Hardness		See No. 17.
Tensile strength per square inch of original section	pounds..	60, 880
Elastic limit per square inch of original section	do ..	39, 000
Elongation per inch after rupture	inch..	0. 02
Elongation per inch under strain at elastic limit	do...	.001267
Reduction in diameter at point of rupture	do...	.014
Reduction in area after rupture, per centum of original section		5. 0
Position of rupture		1. 90 from neck.
Character of broken surface		granular.

This specimen had blow-holes in two places, about .10 and .08 inch diameters. One was in sight, when bar was .8 inch diameter, one appeared when bar was turned down to finished diameters.

Elongation of inch sections: .02 inch, .02 inch, .02 inch, .02 inch (.02 inch fractured section), .02 inch.

No. 358.



[Mark on bar, 2; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load
500	2, 000	.000033	.000033	....	....	
750	3, 000	.000050	.000017	....	....	
1, 000	4, 000	.000067	.000017	....	....	
1, 250	5, 000	.000100	.000033	0.	....	
1, 500	6, 000	.000133	.000033	....	....	
1, 750	7, 000	.000150	.000017	....	....	
2, 000	8, 000	.000167	.000017	....	....	
2, 250	9, 000	.000200	.000033	....	....	
2, 500	10, 000	.000233	.000033	0.	....	
2, 750	11, 000	.000283	.000050	....	....	
3, 000	12, 000	.000317	.000034	....	....	
3, 250	13, 000	.000350	.000033	....	....	
3, 500	14, 000	.000383	.000033	....	....	
3, 750	15, 000	.000417	.000034	0.	....	
4, 000	16, 000	.000450	.000033	....	....	
4, 250	17, 000	.000483	.000033	....	....	
4, 500	18, 000	.000500	.000017	....	....	
4, 750	19, 000	.000533	.000033	....	....	
5, 000	20, 000	.000583	.000050	0.	....	
5, 250	21, 000	.000617	.000034	....	....	
5, 500	22, 000	.000650	.000033	....	....	
5, 750	23, 000	.000683	.000033	....	....	
6, 000	24, 000	.000700	.000017	....	....	
6, 250	25, 000	.000717	.000017	.000033	.000033	
6, 500	26, 000	.000783	.000066	....	....	
6, 750	27, 000	.000800	.000017	....	....	
7, 000	28, 000	.000850	.000050	....	....	
7, 250	29, 000	.000867	.000017	....	....	
7, 500	30, 000	.000883	.000016	.000033	0.	
7, 750	31, 000	.000950	.0000 7	....	....	
8, 000	32, 000	.000967	.000017	....	....	
8, 250	33, 000	.001000	.000033	....	....	
8, 500	34, 000	.001033	.000033	....	....	
8, 750	35, 000	.001083	.000050	.000033	0.	
9, 000	36, 000	.001133	.000050	....	....	
9, 250	37, 000	.001167	.000034	....	....	
9, 500	38, 000	.001200	.000033	....	....	
9, 750	39, 000	.001233	.000033	....	....	
10, 000	40, 000	.001267	.000034	.000050	.000017	
10, 250	41, 000	.001300	.000033	....	....	
10, 500	42, 000	.001350	.000050	....	....	
10, 750	43, 000	.001383	.000033	....	....	Elastic limit.
11, 000	45, 000	.001450	.000067	....	....	
11, 250	45, 000	.001550	.000100	.000183	.000133	
11, 500	46, 000	.002050	.000500	....	....	
11, 750	47, 000	.002317	.000267	....	....	
12, 000	48, 000	.002967	.000650	....	....	
12, 250	49, 000	.003750	.000783	....	....	
12, 500	50, 000	.004467	.000717	.002650	.002467	Micrometer removed.
13, 000	52, 000	.0050	.000533	....	....	
13, 500	54, 000	.0067	.0017	....	....	
14, 000	56, 000	.0083	.0016	....	....	
14, 500	58, 000	.0100	.0017	....	....	
15, 000	60, 000	.0108	.0008	....	....	
15, 500	62, 000	.0117	.0009	....	....	
16, 000	64, 000	.0133	.0016	....	....	
16, 500	66, 000	.0142	.0009	....	....	
17, 000	68, 000	.0150	.0008	....	....	
17, 500	70, 000	.0158	.0008	....	....	
18, 000	72, 000	.0183	.0025	....	....	
18, 280	73, 120	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	73, 120
Elastic limit per square inch of original section	do...	43, 000
Elongation per inch after rupture	inch..	0. 02
Elongation per inch under strain at elastic limit	do...	. 001383
Reduction in diameter at point of rupture	do...	. 014
Reduction in area after rupture, per centum of original section		5. 0
Position of rupture		.25 inch from neck.
Character of broken surface		granular.

There were two small blow-holes in this bar, both of which were turned out when the bar was reduced to .60 inch diameter.

Elongation of inch sections: .02 inch, .02 inch, .01 inch (.03 inch fractured section), .02 inch, .02 inch

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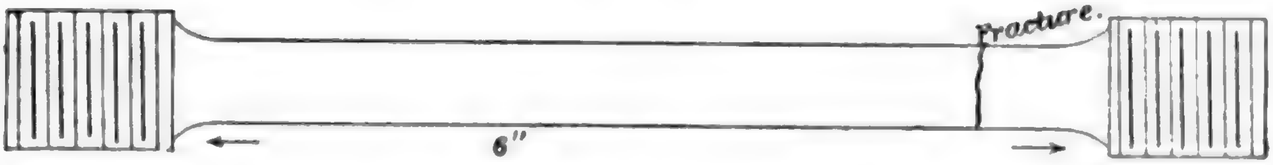
No. 359.



[Mark on bar, 3; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	. 000117	. 000117	0.	....	
2, 500	10, 000	. 000283	. 000166	0.	....	
3, 750	15, 000	. 000433	. 000150	0.	....	
5, 000	20, 000	. 000583	. 000150	0.	....	
5, 250	21, 000	. 000617	. 000034	....	....	
5, 500	22, 000	. 000650	. 000033	....	....	
5, 750	23, 000	. 000667	. 000017	....	....	
6, 000	24, 000	. 000700	. 000033	....	....	
6, 250	25, 000	. 000733	. 000033	0.	....	
6, 500	26, 000	. 000767	. 000034	....	....	
6, 750	27, 000	. 000800	. 000033	....	....	
7, 000	28, 000	. 000833	. 000033	....	....	
7, 250	29, 000	. 000867	. 000034	....	....	
7, 500	30, 000	. 000917	. 000050	. 000017	. 000017	
7, 750	31, 000	. 000933	. 000016	....	....	
8, 000	32, 000	. 000967	. 000034	....	....	
8, 250	33, 000	. 001000	. 000033	....	....	
8, 500	34, 000	. 001067	. 000067	....	....	
8, 750	35, 000	. 001100	. 000033	. 000017	0.	
9, 000	36, 000	. 001133	. 000033	....	....	
9, 250	37, 000	. 001150	. 000017	....	....	
9, 500	38, 000	. 001183	. 000033	....	....	
9, 750	39, 000	. 001233	. 000050	....	....	
10, 000	40, 000	. 001267	. 000034	. 000033	. 000016	
10, 250	41, 000	. 001300	. 000033	....	....	
10, 500	42, 000	. 001333	. 000033	....	....	
10, 750	43, 000	. 001367	. 000034	....	....	
11, 000	44, 000	. 001417	. 000050	....	....	
11, 250	45, 000	. 001450	. 000033	. 000050	. 000017	
11, 500	46, 000	. 001483	. 000033	....	....	
11, 750	47, 000	. 001517	. 000034	....	....	
12, 000	48, 000	. 001567	. 000050	....	....	Elastic limit.
12, 250	49, 000	. 001633	. 000066	....	....	
12, 500	50, 000	. 002033	. 000400	. 000433	. 000383	
12, 750	51, 000	. 002133	. 000100	....	....	
13, 000	52, 000	. 002383	. 000250	....	....	
13, 250	53, 000	. 002633	. 000250	....	....	
13, 500	54, 000	. 003133	. 000500	....	....	
13, 750	55, 000	. 003533	. 000400	. 001633	. 001200	
14, 000	56, 000	. 004083	. 000550	....	....	
14, 250	57, 000	. 004350	. 000267	....	....	

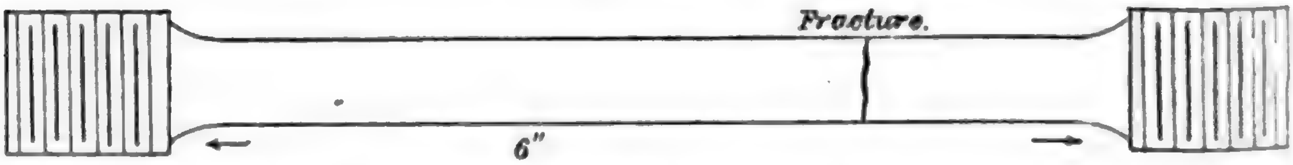
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
14, 500	58, 000	.004917	.000567	....	....	
14, 750	59, 000	.005333	.000416	....	....	
15, 000	60, 000	.006217	.000884	.003967	.002334	Micrometer removed.
15, 500	62, 000	.0067	.000483	....	....	
16, 000	64, 000	.0075	.0008	....	....	
16, 500	66, 000	.0092	.0017	....	....	
17, 000	68, 000	.0108	.0016	....	....	
17, 500	70, 000	.0125	.0017	....	....	
18, 000	72, 000	.0133	.0008	....	....	
18, 500	74, 000	.0150	.0017	....	....	
19, 000	76, 000	.0167	.0017	....	....	
19, 500	78, 000	.0183	.0016	....	....	
20, 000	80, 000	.0200	.0017	....	....	
20, 500	82, 000	.0217	.0017	....	....	
21, 000	84, 000	.0233	.0016	....	....	
21, 500	86, 000	.0250	.0017	....	....	
22, 000	88, 000	.0283	.0033	....	....	
22, 500	90, 000	.0317	.0034	....	....	
23, 000	92, 000	.0333	.0016	....	....	
23, 500	94, 000	.0367	.0034	....	....	
24, 000	96, 000	.0417	.0050	....	....	
24, 360	97, 440	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	97, 440
Elastic limit per square inch of original section	do	48, 000
Elongation per inch after rupture	inch	0. 0383
Elongation per inch under strain at elastic limit	do	.001567
Reduction in diameter at point of rupture	do	.034
Reduction in area after rupture, per centum of original section		11. 8
Position of rupture		.65 inch from neck.
Character of broken surface		granular.

Elongation of inch sections: .03 inch, .03 inch, .03 inch, .03 inch, .05 inch (.05 inch fractured section).

No. 360.



[Mark on bar, 4; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation. per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000117	.000117	0.	....	
2, 500	10, 000	.000283	.000166	0.	....	
3, 750	15, 000	.000400	.000117	0.	....	
5, 000	20, 000	.000567	.000167	0.	....	
5, 250	21, 000	.000600	.000033	....	....	
5, 500	22, 000	.000633	.000033	....	....	
5, 750	23, 000	.000650	.000017	....	....	
6, 000	24, 000	.000683	.000033	....	....	
6, 250	25, 000	.000717	.000034	0.	....	

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
6, 500	26, 000	. 000783	. 000066	....	....	
6, 750	27, 000	. 000800	. 000017	....	....	
7, 000	28, 000	. 000833	. 000033	....	....	
7, 250	29, 000	. 000867	. 000034	....	....	
7, 500	30, 000	. 000900	. 000033	. 000017	. 000017	
7, 750	31, 000	. 000967	. 000067	....	....	
8, 000	32, 000	. 001000	. 000033	....	....	
8, 250	33, 000	. 001033	. 000033	....	....	
8, 500	34, 000	. 001067	. 000034	....	....	
8, 750	35, 000	. 001100	. 000033	. 000050	. 000033	Elastic limit.
9, 000	36, 000	. 001167	. 000067	....	....	
9, 250	37, 000	. 001217	. 000050	....	....	
9, 500	38, 000	. 001283	. 000066	....	....	
9, 750	39, 000	. 001533	. 000250	....	....	
10, 000	40, 000	. 004633	. 003100	. 003217	. 003167	
10, 250	41, 000	. 004967	. 000334	....	....	
10, 500	42, 000	. 005467	. 000500	....	....	
10, 750	43, 000	. 006133	. 000666	....	....	
11, 000	44, 000	. 007217	. 001084	....	....	
11, 250	45, 000	. 007717	. 000500	. 006067	. 002850	Micrometer removed.
11, 500	46, 000	. 0083	. 000583	....	....	
12, 000	48, 000	. 0100	. 0017	....	....	
12, 500	50, 000	. 0117	. 0017	....	....	
13, 000	52, 000	. 0133	. 0016	....	....	
13, 500	54, 000	. 0150	. 0017	....	....	
14, 000	56, 000	. 0167	. 0017	....	....	
14, 500	58, 000	. 0183	. 0016	....	....	
15, 000	60, 000	. 0217	. 0034	....	....	
15, 500	62, 000	. 0233	. 0016	....	....	
16, 000	64, 000	. 0267	. 0034	....	....	
16, 500	66, 000	. 0283	. 0016	....	....	
17, 000	68, 000	. 0333	. 0050	....	....	
17, 500	70, 000	. 0350	. 0017	....	....	
18, 000	72, 000	. 0400	. 0050	....	....	
18, 500	74, 000	. 0433	. 0033	....	....	
19, 000	76, 000	. 0500	. 0067	....	....	
19, 500	78, 000	. 0583	. 0083	....	....	
20, 000	80, 000	. 0650	. 0067	....	....	
20, 500	82, 000	. 0783	. 0133	....	....	
21, 000	84, 000	. 0950	. 0167	....	....	
21, 500	86, 000	. 1250	. 0300	....	....	
21, 600	86, 400	. 1450	. 0200	....	....	Ultimate strength.
16, 500	....	....	....	....	....	Load at time of fracture.

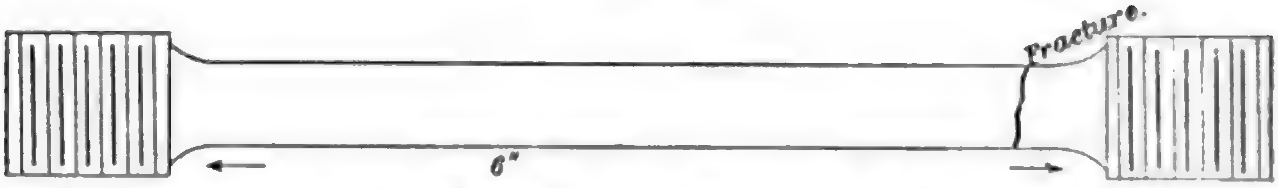
GENERAL SUMMARY.

Specific gravity	
Hardness	
Tensile strength per square inch of original section ....pounds..	86, 400
Elastic limit per square inch of original section ....do...	35, 000
Elongation per inch after rupture ....inch..	0. 1483
Elongation per inch under strain at elastic limit ....do...	. 001100
Reduction in diameter at point of rupture ....do...	. 084
Reduction in area after rupture, per centum of original section	27. 6
Position of rupture	1.20 inches from neck.
Character of broken surface	granular, 60 per cent. ; dull smoky, 40 per cent.

The metal separated first at the dull smoky section. Seven small cracks developed along the surface of the stem.

Elongation of inch sections: .11 inch, .14 inch, .13 inch, .14 inch (.16 inch fractured section, .21 inch).

No. 361.



[Mark on bar, 5; diameter. .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000067	.000067	0.	....	
2,500	10,000	.000217	.000150	0.	....	
3,750	15,000	.000400	.000183	0.	....	
5,000	20,000	.000533	.000133	0.	....	
5,250	21,000	.000583	.000050	....	....	
5,500	22,000	.000617	.000034	....	....	
5,750	23,000	.000650	.000033	....	....	
6,000	24,000	.000667	.000017	....	....	
6,250	25,000	.000717	.000050	0.	....	
6,500	26,000	.000733	.000016	....	....	
6,750	27,000	.000800	.000067	....	....	
7,000	28,000	.000833	.000033	....	....	
7,250	29,000	.000867	.000034	....	....	
7,500	30,000	.000883	.000016	0.	....	
7,750	31,000	.000950	.000067	....	....	
8,000	32,000	.000983	.000033	....	....	
8,250	33,000	.001033	.000050	....	....	
8,500	34,000	.001083	.000050	....	....	
8,750	35,000	.001117	.000034	.000067	.000067	Elastic limit.
9,000	36,000	.001167	.000050	....	....	
9,250	37,000	.001233	.000066	....	....	
9,500	38,000	.001467	.000234	....	....	
9,750	39,000	.001917	.000450	....	....	
10,000	40,000	.005267	.003350	.003867	.003800	
10,250	41,000	.005567	.000300	....	....	
10,500	42,000	.006167	.000600	....	....	
10,750	43,000	.006800	.000633	....	....	
11,000	44,000	.007633	.000833	....	....	
11,250	45,000	.008383	.000750	.006700	.002833	
11,500	46,000	.008983	.000600	....	....	
11,750	47,000	.009700	.000717	....	....	
12,000	48,000	.010667	.000967	....	....	
12,250	49,000	.011467	.000800	....	....	
12,500	50,000	.012333	.000866	....	....	Micrometer removed.
13,000	52,000	.0133	.000967	....	....	
13,500	54,000	.0150	.0017	....	....	
14,000	56,000	.0183	.0033	....	....	
14,500	58,000	.0200	.0017	....	....	
15,000	60,000	.0217	.0017	....	....	
15,500	62,000	.0250	.0033	....	....	
16,000	64,000	.0283	.0033	....	....	
16,500	66,000	.0300	.0017	....	....	
17,000	68,000	.0350	.0050	....	....	
17,500	70,000	.0383	.0033	....	....	
18,000	72,000	.0417	.0034	....	....	
18,500	74,000	.0467	.0050	....	....	
19,000	76,000	.0533	.0066	....	....	
19,500	78,000	.0600	.0067	....	....	
20,000	80,000	.0700	.0100	....	....	
20,500	82,000	.0817	.0117	....	....	
21,000	84,000	.1000	.0183	....	....	
21,500	86,000	.1367	.0367	....	....	Ultimate strength.

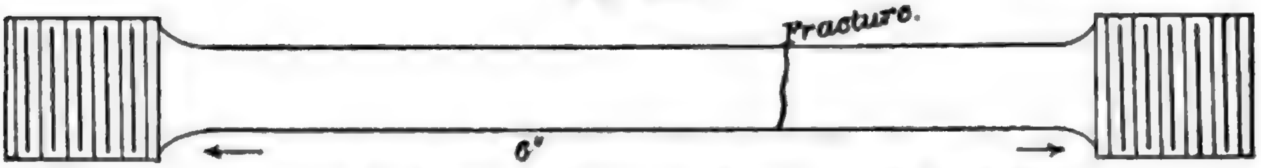
GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	86,000
Elastic limit per square inch of original section	do. ..	35,000
Elongation per inch after rupture	inch..	0.14
Elongation per inch under strain at elastic limit	do...	.001117
Reduction in diameter at point of rupture	do...	.064
Reduction in area after rupture, per centum of original section		21.4
Position of rupture		.8 inch from neck.

Character of broken surface......granular, 60 per cent.; dull spongy, 40 per cent. Seven small cracks developed along the surface of the stem.

ngation of inch sections: .11 inch, .14 inch, .14 inch, 14 inch, .13 inch (.18 inch fractured section).

No. 362.



[Mark on bar, 6; diameter, .564 inch; sectional area, .25 square inch.]

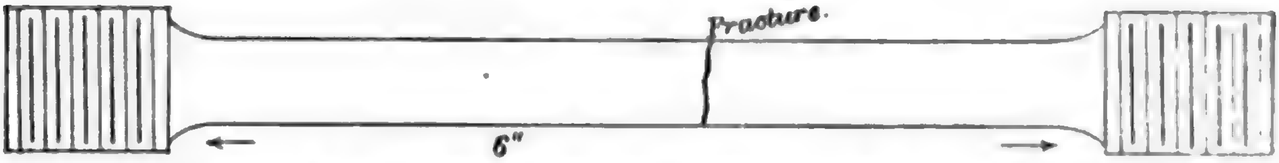
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000283	.000182	0.	....	
3, 750	15, 000	.000417	.000134	0.	....	
5, 000	20, 000	.000567	.000150	0.	....	
5, 250	21, 000	.000600	.000033	....	....	
5, 500	22, 000	.000633	.000033	....	....	
5, 750	23, 000	.000667	.000034	....	....	
6, 000	24, 000	.000700	.000033	....	....	
6, 250	25, 000	.000750	.000050	.000017	.000017	
6, 500	26, 000	.000783	.000033	....	....	
6, 750	27, 000	.000817	.000034	....	....	
7, 000	28, 000	.000850	.000033	....	....	
7, 250	29, 000	.000883	.000033	....	....	
7, 500	30, 000	.000933	.000050	.000033	.000016	
7. 750	31, 000	.000967	.000034	....	....	
8, 000	32, 000	.001000	.000033	....	....	
8, 250	33, 000	.001033	.000033	....	....	
8, 500	34, 000	.001083	.000050	....	....	
8, 750	35, 000	.001117	.000034	.000067	.000034	
9, 000	36, 000	.001167	.000050	....	....	
9, 250	37, 000	.001200	.000033	....	....	Elastic limit.
9, 500	38, 000	.001250	.000050	....	....	
9. 750	39, 000	.001333	.000083	....	....	
10, 000	40, 000	.002350	.001017	.001067	.001000	
10, 250	41, 000	.004833	.002483	....	....	
10, 500	42, 000	.005550	.000717	....	....	
10, 750	43, 000	.006000	.000450	....	....	
11, 000	44, 000	.006917	.000917	....	....	
11, 250	45, 000	.007950	.001033	.006250	.005183	
11, 500	46, 000	.008383	.000433	....	....	
11, 750	47, 000	.008900	.000517	....	....	
12, 000	48, 000	.009633	.000733	....	....	
12, 250	49, 000	.010367	.000734	....	....	
12, 500	50, 000	.011200	.000833	.009300	.003050	
13, 000	52, 000	.013067	.001867	....	....	
13, 500	54, 000	.014633	.001566	....	....	
14, 000	56, 000	.016633	.002000	....	....	
14, 500	58, 000	.018817	.002184	....	....	
15, 000	60, 000	.020883	.002066	....	....	Micrometer removed.
15, 500	62, 000	.0225	.001617	....	....	
16, 000	64, 000	.0250	.0025	....	....	
16, 500	66, 000	.0267	.0017	....	....	
17, 000	68, 000	.0300	.0033	....	....	
17, 500	70, 000	.0317	.0017	....	....	
18, 000	72, 000	.0350	.0033	....	....	
18, 500	74, 000	.0400	.0050	....	....	
19, 000	76, 000	.0467	.0067	....	....	
19, 500	78, 000	.0500	.0033	....	....	
20, 000	80, 000	.0583	.0083	....	....	
20, 500	82, 000	.0650	.0067	....	....	
21, 000	84, 000	.0750	.0100	....	....	
21. 500	86, 000	.0900	.0150	....	....	
22, 000	88, 000	.1217	.0317	....	....	
22, 200	88, 800	.1567	.0350	....	....	Ultimate strength.
21, 600	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity	
Hardness	
Tensile strength per square inch of original section ... pounds..	88, 800
Elastic limit per square inch of original section ... do ...	37, 000
Elongation, ultimate ... inch..	0. 1717
Elongation per inch at elastic limit ... do....	.001200
Reduction in diameter, ultimate ... do ...	.064
Reduction in area after rupture, per centum of original section ...	21. 4
Position of rupture ...	.60 inch from middle of stem.
Character of broken surface ...	granular, with a dull spot (.30 per cent. of surface) at circumference.

Elongation of inch sections: .12 inch, .17 inch .16 inch (.25 inch fractured section), .18 inch, .15 inch.

No. 363.



[Mark on bar, 7: diameter, .564 inch; sectional area, .25 square inch.]

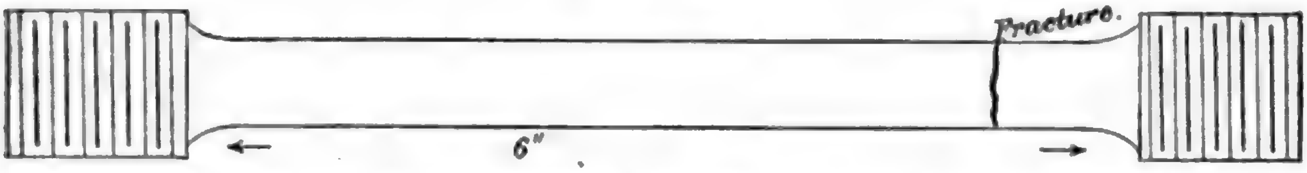
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000100	.000100	0.	....	
2,500	10,000	.000200	.000100	0.	....	
3,750	15,000	.000367	.000167	0.	....	
5,000	20,000	.000517	.000150	0.	....	
5,250	21,000	.000550	.000033	....	....	
5,500	22,000	.000583	.000033	....	....	
5,750	23,000	.000633	.000050	....	....	
6,000	24,000	.000650	.000017	....	....	
6,250	25,000	.000667	.000017	0.	....	
6,500	26,000	.000700	.000033	....	....	
6,750	27,000	.000733	.000033	....	....	
7,000	28,000	.000767	.000034	....	....	
7,250	29,000	.000800	.000033	....	....	
7,500	30,000	.000833	.000033	0.	....	
7,750	31,000	.000867	.000034	....	....	
8,000	32,000	.000933	.000066	....	....	
8,250	33,000	.000967	.000034	....	....	
8,500	34,000	.001000	.000033	....	....	
8,750	35,000	.001033	.000 33	0.	....	Elastic limit.
9,000	36,000	.001100	.000067	....	....	
9,250	37,000	.001217	.000117	....	....	
9,500	38,000	.001400	.000183	....	....	
9,750	39,000	.001633	.000233	....	....	
10,000	40,000	.002000	.000367	.000750	.000750	
10,250	41,000	.002383	.000383	....	....	
10,500	42,000	.002717	.000334	....	....	
10,750	43,000	.002900	.000183	....	....	
11,000	44,000	.063300	.000400	....	....	
11,250	45,000	.003717	.000417	.002317	.001567	
11,500	46,000	.004317	.000600	....	....	
11,750	47,000	.004883	.000566	....	....	
12,000	48,000	.005667	.000784	....	....	
12,250	49,000	.006217	.000550	....	....	
12,500	50,000	.006983	.000766	.005217	.002900	
13,000	52,000	.008467	.001484	....	....	
13,500	54,000	.009667	.001200	....	....	
14,000	56,000	.011033	.001366	....	....	
14,500	58,000	.012550	.001517	....	....	
15,000	60,000	.014700	.002150	....	....	Micrometer removed.
15,500	62,000	.0167	.0020	....	....	
16,000	64,000	.0183	.0016	....	....	
16,500	66,000	.0200	.0017	....	....	
17,000	68,000	.0233	.0033	....	....	
17,500	70,000	.0250	.0017	....	....	
18,000	72,000	.0267	.0017	....	....	
18,500	74,000	.0300	.0033	....	....	
19,000	76,000	.0317	.0017	....	....	
19,500	78,000	.0350	.0033	....	....	
20,000	80,000	.0400	.0050	....	....	
20,350	81,400	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity	
Hardness	
Tensile strength per square inch of original section ....pounds..	81,400
Elastic limit per square inch of original section ....do...	35,000
Elongation per inch after rupture ....inch..	0.04
Elongation per inch under strain at elastic limit ....do..	.001033
Reduction in diameter at point of rupture ....do..	.014
Reduction in area after rupture, per centum of original section	5.0
Position of rupture	50 inch from middle of stem.
Character of broken surface	granular.

Elongation of inch sections: .03 inch, .02 inch, .03 inch (.05 inch fractured section), .07 inch, .04 inch.

No. 364.



[Mark on bar, 8; diameter, .564 inch; sectional area, .25 square inch; bar has blow-hole in stem .04 inch diameter]

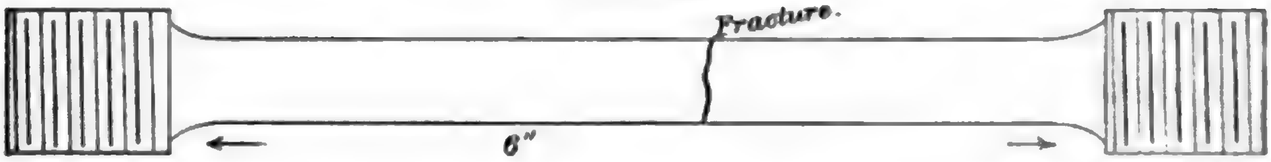
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.	....	
2, 500	10, 000	.000250	.000167	0.	....	
3, 750	15, 000	.000383	.000133	0.	....	
5, 000	20, 000	.000550	.000167	0.	....	
5, 250	21, 000	.000567	.000017	....	....	
5, 500	22, 000	.000600	.000033	....	....	
5, 750	23, 000	.000633	.000033	....	....	
6, 000	24, 000	.000650	.000017	....	....	
6, 250	25, 000	.000683	.000033	0.	....	
6, 500	26, 000	.000700	.000017	....	....	
6, 750	27, 000	.000750	.000050	....	....	
7, 000	28, 000	.000800	.000050	....	....	
7, 250	29, 000	.000833	.000033	....	....	
7, 500	30, 000	.000850	.000017	0.	....	
7, 750	31, 000	.000883	.000033	....	....	
8, 000	32, 000	.000950	.000067	....	....	
8, 250	33, 000	.000983	.000033	....	....	
8, 500	34, 000	.001017	.000034	....	....	
8, 750	35, 000	.001033	.000016	.000017	.000017	
9, 000	36, 000	.001067	.000034	....	....	
9, 250	37, 000	.001117	.000050	....	....	
9, 500	38, 000	.001150	.000033	....	....	
9, 750	39, 000	.001183	.000033	....	....	Elastic limit.
10, 000	40, 000	.001533	.000350	.000383	.000366	
10, 250	41, 000	.002050	.000517	....	....	
10, 500	42, 000	.002633	.000583	....	....	
10, 750	43, 000	.002967	.000334	....	....	
11, 000	44, 000	.003533	.000566	....	....	
11, 250	45, 000	.004017	.000484	.002533	.002150	
11, 500	46, 000	.004467	.000450	....	....	
11, 750	47, 000	.004783	.000316	....	....	Micrometer removed.
12, 000	48, 000	.0058	.001017	....	....	
12, 250	49, 000	.0067	.0009	....	....	
12, 500	50, 000	.0083	.0016	....	....	
13, 000	52, 000	.0092	.0009	....	....	
13, 500	54, 000	.0117	.0025	....	....	
14, 000	56, 000	.0125	.0008	....	....	
14, 500	58, 000	.0133	.0008	....	....	
15, 000	60, 000	.0150	.0017	....	....	
15, 500	62, 000	.0167	.0017	....	....	
16, 000	64, 000	.0183	.0016	....	....	
16, 500	66, 000	.0200	.0017	....	....	
17, 000	68, 000	.0217	.0017	....	....	
17, 500	70, 000	.0250	.0033	....	....	
18, 000	72, 000	.0283	.0033	....	....	
18, 500	74, 000	.0300	.0017	....	....	
19, 000	76, 000	.0333	.0033	....	....	
19, 500	78, 000	.0367	.0034	....	....	
20, 000	80, 000	.0400	.0033	....	....	
20, 500	82, 000	.0450	.0050	....	....	
21, 000	84, 000	.0500	.0050	....	....	
21, 010	84, 040	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	84, 040
Elastic limit per square inch of original section	do...	39, 000
Elongation per inch after rupture	inch..	0. 05
Elongation per inch under strain at elastic limit	do...	.001183
Reduction in diameter at point of rupture	do...	.024
Reduction in area after rupture, per centum of original section		8. 4
Position of rupture		.80 inch from neck, and .60 inch from .04 inch blow-hole.
Character of broken surface		granular.

Elongation of inch sections: .03 inch, .03 inch, .04 inch, .06 inch, .06 inch (.08 inch fractured section).

No. 365.



[Mark on bar, 9; diameter, .564 inch; sectional area, .25 square inch.]

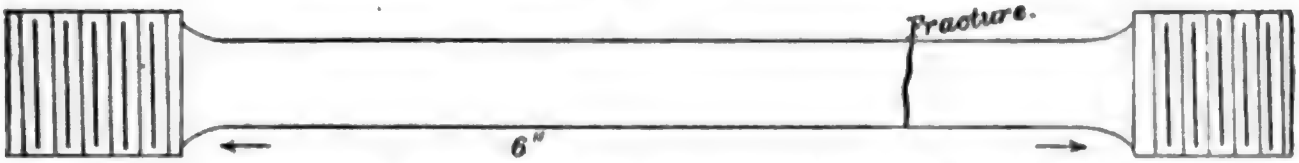
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000067	.000067	0.		
2,500	10,000	.000217	.000150	0.		
3,750	15,000	.000367	.000150	0.		
5,000	20,000	.000550	.000183	0.		
5,250	21,000	.000567	.000017			
5,500	22,000	.000600	.000033			
5,750	23,000	.000633	.000033			
6,000	24,000	.000667	.000034			
6,250	25,000	.000700	.000033	0.		
6,500	26,000	.000733	.000033			
6,750	27,000	.000783	.000050			
7,000	28,000	.000817	.000034			
7,250	29,000	.000850	.000033			
7,500	30,000	.000917	.000067	.000033	.000033	
7,750	31,000	.000967	.000050			
8,000	32,000	.001000	.000033			
8,250	33,000	.001033	.000033			
8,500	34,000	.001083	.000050			
8,750	35,000	.001133	.000050	.000117	.000084	
9,000	36,000	.001183	.000050			Elastic limit.
9,250	37,000	.001267	.000084			
9,500	38,000	.001350	.000083			
9,750	39,000	.001550	.000200			
10,000	40,000	.003500	.001950	.002217	.002100	
10,250	41,000	.003817	.000317			
10,500	42,000	.004467	.000650			
10,750	43,000	.005133	.000666			
11,000	44,000	.005700	.000567			
11,250	45,000	.006300	.000600	.004783	.002566	
11,500	46,000	.007050	.000750			
11,750	47,000	.007700	.000650			
12,000	48,000	.008467	.000767			
12,250	49,000	.009200	.000733			
12,500	50,000	.010050	.000850	.008217	.003434	
13,000	52,000	.011650	.001600			
13,500	54,000	.013300	.001650			
14,000	56,000	.015383	.002083			
14,500	58,000	.017033	.001650			
15,000	60,000	.019000	.001967			Micrometer removed.
15,500	62,000	.0217	.0027			
16,000	64,000	.0233	.0016			
16,500	66,000	.0250	.0017			
17,000	68,000	.0283	.0033			
17,500	70,000	.0325	.0042			
18,000	72,000	.0350	.0025			
18,500	74,000	.0383	.0033			
19,000	76,000	.0433	.0050			
19,500	78,000	.0467	.0034			
20,000	80,000	.0550	.0083			
20,500	82,000	.0633	.0083			
21,000	84,000	.0717	.0084			
21,500	86,000	.0883	.0166			
21,930	87,720	.1133	.0250			Ultimate strength.
20,800						Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	87,720
Elastic limit per square inch of original section	do	36,000
Elongation per inch after rupture	inch	0.1117
Elongation per inch under strain at elastic limit	do	.001183
Reduction in diameter at point of rupture	do	.054
Reduction in area after rupture, per centum of original section		18.3
Position of rupture		.50 inch from middle of stem.
Character of broken surface		granular, 70 per cent.; dull spongy spot at circumference, 30 per cent.

Elongation of inch sections: .09 inch, .09 inch, .11 inch (.14 inch fractured section), .13 inch, .11 inch.

No. 366.



[Mark on bar, 10; diameter, .564 inch; sectional area, .25 square inch.]

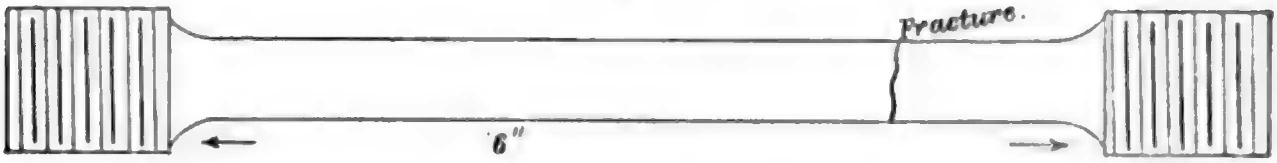
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.	....	
2, 500	10, 000	.000267	.000184	0.	....	
3, 750	15, 000	.000417	.000150	0.	....	
5, 000	20, 000	.000583	.000166	0.	....	
5, 250	21, 000	.000600	.000017	....	....	
5, 500	22, 000	.000633	.000033	....	....	
5, 750	23, 000	.000667	.000034	....	....	
6, 000	24, 000	.000700	.000033	....	....	
6, 250	25, 000	.000733	.000033	0.	....	
6, 500	26, 000	.000783	.000050	....	....	
6, 750	27, 000	.000833	.000050	....	....	
7, 000	28, 000	.000867	.000034	....	....	
7, 250	29, 000	.000917	.000050	....	....	
7, 500	30, 000	.000967	.000050	.000050	.000050	
7, 750	31, 000	.001000	.000033	....	....	
8, 000	32, 000	.001050	.000050	....	....	
8, 250	33, 000	.001083	.000033	....	....	
8, 500	34, 000	.001133	.000050	....	....	
8, 750	35, 000	.001167	.000034	.000100	.000050	
9, 000	36, 000	.001233	.000066	....	....	
9, 250	37, 000	.001283	.000050	....	....	Elastic limit.
9, 500	38, 000	.001383	.000100	....	....	
9, 750	39, 000	.001517	.000134	....	....	
10, 000	40, 000	.003217	.001700	.001867	001767	
10, 250	41, 000	.003767	.000550	....	....	
10, 500	42, 000	.004333	.000566	....	....	
10, 750	43, 000	.004783	.000450	....	....	
11, 000	44, 000	.005883	.001100	....	....	
11, 250	45, 000	.006200	.000317	.004583	.002716	
11, 500	46, 000	.006800	.000600	....	....	
11, 750	47, 000	.007383	.000583	....	....	
12, 000	48, 000	.008300	.000917	....	....	
12, 250	49, 000	.008967	.000667	....	....	
12, 500	50, 000	.009700	.000733	.007783	.003200	
13, 000	52, 000	.011500	.001800	....	....	
13, 500	54, 000	.013267	.001767	....	....	
14, 000	56, 000	.014533	.001266	....	....	
14, 500	58, 000	.016750	.002217	....	....	
15, 000	60, 000	.018967	.002217	....	....	Micrometer removed.
15, 500	62, 000	.0208	.001833	....	....	
16, 000	64, 000	.0225	.0017	....	....	
16, 500	66, 000	.0250	.0025	....	....	
17, 000	68, 000	.0267	.0017	....	....	
17, 500	70, 000	.0317	.0050	....	....	
18, 000	72, 000	.0350	.0033	....	....	
18, 500	74, 000	.0383	.0033	....	....	
19, 000	76, 000	.0417	.0034	....	....	
19, 500	78, 000	.0483	.0066	....	....	
20, 000	80, 000	.0533	.0050	....	....	
20, 500	82, 000	.0600	.0067	....	....	
21, 000	84, 000	.0700	.0100	....	....	
21, 500	86, 000	.0833	.0133	....	....	
22, 000	88, 000	.1050	.0217	....	....	
22, 200	88, 800	.1283	.0233	....	....	Ultimate strength.
21, 000	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	88, 800
Elastic limit per square inch of original section	do ...	37, 000
Elongation per inch after rupture	inch..	0. 1283
Elongation per inch under strain at elastic limit	do....	.001283
Reduction in diameter at point of rupture	do....	.064
Reduction in area after rupture, per centum of original section		21.4
Position of rupture		1. 30 inch from neck.
Character of broken surface		granular, 50 per cent.; dull spongy, 50 per cent.

Elongation of inch sections: .09 inch, .11 inch, .13 inch, .14 inch (.19 inch fractured section)., 11 inch.

No. 367.



[Mark on bar, 11; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.		
2, 500	10, 000	.000233	.000150	0.		
3, 750	15, 000	.000400	.000167	0.		
5, 000	20, 000	.000567	.000167	0.		
5, 250	21, 000	.000583	.000016			
5, 500	22, 000	.000617	.000034			
5, 750	23, 000	.000650	.000033			
6, 000	24, 000	.000683	.000033			
6, 250	25, 000	.000700	.000017	.000017	.000017	
6, 500	26, 000	.000750	.000050			
6, 750	27, 000	.000783	.000033			
7, 000	28, 000	.000833	.000050			
7, 250	29, 000	.000850	.000017			
7, 500	30, 000	.000900	.000050	.000033	.000016	
7, 750	31, 000	.000950	.000050			
8, 000	32, 000	.001000	.000050			
8, 250	33, 000	.001033	.000033			
8, 500	34, 000	.001083	.000050			
8, 750	35, 000	.001117	.000034	.000050	.000017	
9, 000	36, 000	.001133	.000016			
9, 250	37, 000	.001167	.000034			
9, 500	38, 000	.001217	.000050			
9, 750	39, 000	.001283	.000066			
10, 000	40, 000	.001350	.000067	.000100	.000050	Elastic limit.
10, 250	41, 000	.001683	.000333			
10, 500	42, 000	.002150	.000467			
10, 750	43, 000	.003833	.001683			
11, 000	44, 000	.004700	.000867			
11, 250	45, 000	.005300	.000600	.003717	.003617	
11, 500	46, 000	.005983	.000683			
11, 750	47, 000	.006283	000300			
12, 000	48, 000	.007033	.000750			
12, 250	49, 000	.007717	.000684			
12, 500	50, 000	.008633	.000916	.006750	.003033	
13, 000	52, 000	.009883	.001250			
13, 500	54, 000	.011283	.001400			
14, 000	56, 000	.012650	.001367			
14, 500	58, 000	.014133	.001483			
15, 000	60, 000	.016367	.002234			Micrometer removed.
15, 500	62, 000	.0183	.001933			
16, 000	64, 000	.0200	.0017			
16, 500	66, 000	.0225	.0025			
17, 000	68, 000	.0250	.0025			
11, 500	70, 000	.0267	.0017			
18, 000	72, 000	.0283	.0016			
18, 500	74, 000	.0317	.0034			
19, 000	76, 000	.0333	.0016			
19, 500	78, 000	.0367	.0034			
19, 620	78, 480					Ultimate strength.

GENERAL SUMMARY.

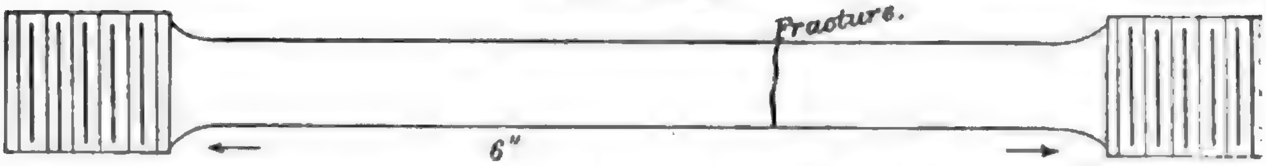
Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	78, 480
Elastic limit per square inch of original section	do...	40, 000
Elongation per inch after rupture	inch..	0. 035
Elongation per inch under strain at elastic limit	do...	.001350
Reduction in diameter at point of rupture	do...	.024
Reduction in area after rupture, per centum of original section		8. 4
Position of rupture		1.50 inches from neck.
Character of broken surface		granular.

Several small blow-holes along the length of the stem were in sight when the bar was roughed out. They all turned out except one, one-eighth inch diameter, 1¼ inches from neck.

Bar did not fracture at the blow-hole.

Elongation of inch sections: 0.3 inch, .03 inch, .03 inch, .04 inch (.05 inch fractured section), .03 inch.

No. 368.



[Mark on bar, 12; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0	0.	0.	0.	Initial load.
1,250	5,000	.000100	.000100	0.	....	
2,500	10,000	.000267	.000167	0.	....	
3,750	15,000	.000433	.000166	0.	....	
5,000	20,000	.000600	.000167	.000017	.000017	
5,250	21,000	.000617	.000017	....	....	
5,500	22,000	.000633	.000016	....	....	
5,750	23,000	.000667	.000034	....	....	
6,000	24,000	.000683	.000016	....	....	
6,250	25,000	.000717	.000034	.000033	.000016	
6,500	26,000	.000767	.000050	....	....	
6,750	27,000	.000800	.000033	....	....	
7,000	28,000	.000833	.000033	....	....	
7,250	29,000	.000867	.000034	....	....	
7,500	30,000	.000917	.000050	.000050	.000017	
7,750	31,000	.000933	.000016	....	....	
8,000	32,000	.000983	.000050	....	....	
8,250	33,000	.001017	.000034	....	....	
8,500	34,000	.001050	.000034	....	....	
8,750	35,000	.001083	.000033	.000050	0.	
9,000	36,000	.001100	.000017	....	....	
9,250	37,000	.001133	.000033	....	....	
9,500	38,000	.001183	.000050	....	....	
9,750	39,000	.001217	.000034	....	....	
10,000	40,000	.001267	.000050	.000067	.000017	
10,250	41,000	.001300	.000033	....	....	
10,500	42,000	.001367	.000067	....	....	
10,750	43,000	.001367	0.	....	....	Elastic limit.
11,000	44,000	.001433	.000066	....	....	
11,250	45,000	.001500	.000067	.000150	.000083	
11,500	46,000	.001700	.000200	....	....	
11,750	47,000	.002367	.000667	....	....	
12,000	48,000	.003667	.001300	....	....	
12,250	49,000	.004350	.000683		....	
12,500	50,000	.005000	.000650	.003250	.003100	
13,000	52,000	.006033	.001033	....	....	
13,500	54,000	.007133	.001100	....	....	
14,000	56,000	.008333	.001200	....	....	
14,500	58,000	.009700	.001367	....	....	
15,000	60,000	.010883	.001183	....	....	
15,500	62,000	.012333	.001450	....	....	
16,000	64,000	.013833	.001500	....	....	
16,500	66,000	.015250	.001417	....	....	
17,000	68,000	.016667	001417	....	....	
17,500	70,000	.018433	001766	....	....	Micrometer removed.
18,000	72,000	.0217	.003267	....	....	
18,500	74,000	.0225	.0008	....	....	
19,000	76,000	.0250	.0025	....	....	
19,500	78,000	.0267	.0017	....	....	
20,000	80,000	.0283	.0016	....	....	
20,500	82,000	.0317	.0034	....	....	
21,000	84,000	.0333	.0016	....	....	
21,500	86,000	....	....	....	....	Ultimate strength

GENERAL SUMMARY.

Specific gravity	
Hardness	
Tensile strength per square inch of original section .... pounds..	86,000
Elastic limit per square inch of original section .... do ..	43,000
Elongation per inch after rupture .... inches..	0.035
Elongation per inch under strain at elastic limit .... do ...	.001367
Reduction in diameter at point of rupture .... do....	.014
Reduction in area after rupture, per centum of original section	5.0
Position of rupture	2.10 inches from neck.
Character of broken surface	granular.

There were two small blow-holes in sight when the stem was 1.00 inch diameter. Both turned out when the bar was reduced to .6 inch diameter.

Bar fractured at a blow-hole .03 inch diameter and one-fourth inch deep.

Elongation of inch sections: .02 inch, .03 inch, .03 inch (.06 inch fractured section), .03 inch, .04 inch

No. 369.

[Mark on bar, 13; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	Initial load.
250	1, 000	0.	0.	0.	0.	
1, 250	5, 000	.000117	.000117	0.	....	
2, 500	10, 000	.000283	.000166	.000017	.000017	
3, 750	15, 000	.000450	.000167	.000017	0.	
5, 000	20, 000	.000600	.000150	.000033	.000016	
5, 250	21, 000	.000617	.000017	....	....	
5, 500	22, 000	.000633	.000016	....	....	
5, 750	23, 000	.000667	.000034	....	....	
6, 000	24, 000	.000717	.000050	....	....	
6, 250	25, 000	.000750	.000033	.000050	.000017	
6, 500	26, 000	.000783	.000033	....	....	
6, 750	27, 000	.000817	.000034	....	....	
7, 000	28, 000	.000850	.000033	....	....	
7, 250	29, 000	.000883	.000033	....	....	
7, 500	30, 000	.000917	.000034	.000050	0.	
7, 750	31, 000	.000967	.000050	....	....	
8, 000	32, 000	.001000	.000033	....	....	
8, 250	33, 000	.001033	.000033	....	....	
8, 500	34, 000	.001083	.000050	....	....	
8, 750	35, 000	.001117	.000034	.000067	.000017	
9, 000	36, 000	.001133	.000016	....	....	
9, 250	37, 000	.001167	.000034	....	....	
9, 500	38, 000	.001217	.000050	....	....	
9, 750	39, 000	.001233	.000016	....	....	
10, 000	40, 000	.001283	.000050	.000083	.000016	
10, 250	41, 000	.001300	.000017	....	....	
10, 500	42, 000	.001333	.000033	....	....	
10, 750	43, 000	.001383	.000050	....	....	
11, 000	44, 000	.001433	.000050	....	....	
11, 250	45, 000	.001483	.000050	.000117	.000034	
11, 500	46, 000	.001533	.000050	....	....	
11, 750	47, 000	.001550	.000017	....	....	Elastic limit.
12, 000	48, 000	.001967	.000417	....	....	
12, 250	49, 000	.002633	.000666	....	....	
12, 500	50, 000	.004350	.001717	.002583	.002466	
13, 000	52, 000	.005233	.000883	....	....	
13, 500	54, 000	.006217	.000984	....	....	
14, 000	56, 000	.007483	.001266	....	....	
14, 500	58, 000	.008717	.001234	....	....	
15, 000	60, 000	.010050	.001333	....	....	
15, 500	62, 000	.011517	.001467	....	....	
16, 000	64, 000	.012833	.001316	....	....	
16, 500	66, 000	.014400	.001567	....	....	
17, 000	68, 000	.016000	.001600	....	....	
17, 500	70, 000	.017967	.001967	....	....	Micrometer removed.
18, 000	72, 000	.0217	.003733	....	....	
18, 500	74, 000	.0233	.0016	....	....	
19, 000	76, 000	.0250	.0017	....	....	
19, 500	78, 000	.0275	.0025	....	....	
20, 000	80, 000	.0292	.0017	....	....	
20, 500	82, 000	.0317	.0025	....	....	
21, 000	84, 000	.0367	.0050	....	....	Ultimate strength.
20, 500	....	....	....	....	....	Load at time of fracture.

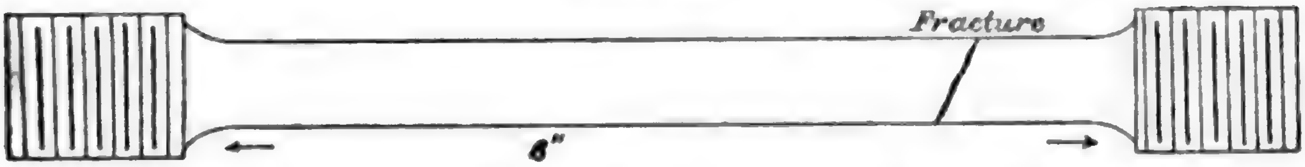
GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	84, 000
Elastic limit per square inch of original section	do	47, 000
Elongation per inch after rupture	inch	0.035
Elongation per inch under strain at elastic limit	do	.001550
Reduction in diameter at point of rupture	do	.024
Reduction in area after rupture, per centum of original section		8.4
Position of rupture		.35 inch from neck.
Character of broken surface		granular. Dull spot at circumference, 20 per cent. A number of crystals with very bright facets are contained in this dull spot.

Elongation of inch sections: .03 inch, .03 inch, .03 inch, .03 inch, .03 inch (.06 fractured section).

Two blow-holes in sight when stem was 1⅛ inches diameter; both turned out when reduced to .6 inch.

No. 370.



[Mark on bar, 14; diameter, .564 inch; sectional area, .25 square inch.]

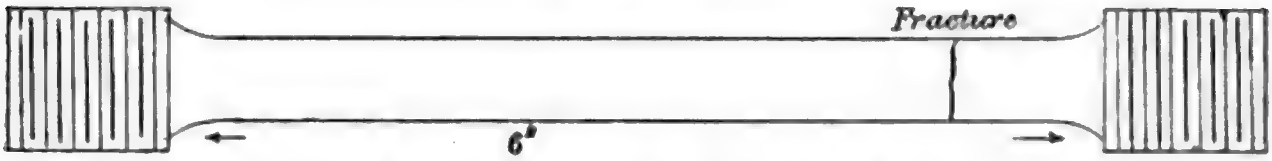
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1,000	0.	0.	0.	0.	Initial load.
1,250	5,000	.000067	.000067	0.		
2,500	10,000	.000217	.000150	0.		
3,750	15,000	.000367	.000150	0.		
5,000	20,000	.000500	.000133	0.		
5,250	21,000	.000550	.000050			
5,500	22,000	.000600	.000050			
5,750	23,000	.000617	.000017			
6,000	24,000	.000633	.000016			
6,250	25,000	.000683	.000050	0.		
6,500	26,000	.000717	.000034			
6,750	27,000	.000750	.000033			
7,000	28,000	.000783	.000033			
7,250	29,000	.000833	.000050			
7,500	30,000	.000867	.000034	.000017	.000017	
7,750	31,000	.000933	.000066			
8,000	32,000	.000967	.000034			
8,250	33,000	.001000	.000033			
8,500	34,000	.001050	.000050			
8,750	35,000	.001100	.000050	.000050	.000033	
9,000	36,000	.001133	.000033			
9,250	37,000	.001183	.000050			
9,375	37,500	.001200	.000017			Elastic limit.
9,500	38,000	.001300 .004383	.000100 .003083			
9,750	39,000	.006767	.002384			
10,000	40,000	.008050	.001283	.006567	.006517	
10,250	41,000	.008550	.000500			
10,500	42,000	.009450	.000900			
10,750	43,000	.009967	.000517			
11,000	44,000	.011250	.001283			
11,250	45,000	.012033	.000783	.010350	.003783	
11,500	46,000	.012833	.000800			
11,750	47,000	.013800	.000967			
12,000	48,000	.014867	.001067			
12,250	49,000	.015533	.000666			
12,500	50,000	.017000	.001467	.014967	.004617	
13,000	52,000	.018850	.001850			
13,500	54,000	.021483	.002633			
14,000	56,000	.023750	.002267			
14,500	58,000	.027217	.003467			
15,000	60,000	.029817	.002600			Micrometer removed.
15,500	62,000	.0333	.003483			
16,000	64,000	.0383	.0050			
16,500	66,000	.0433	.0050			
17,000	68,000	.0467	.0034			
17,500	70,000	.0550	.0083			
18,000	72,000	.0600	.0050			
18,500	74,000	.0700	.0100			
19,000	76,000	.0800	.0100			
19,500	78,000	.0983	.0183			
20,000	80,000	.1283	.0300			
20,120	80,480	.1567	.0284			Ultimate strength.
19,300						Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	80,480
Elastic limit per square inch of original section	do ...	37,500
Elongation per inch after rupture	inch..	0.18
Elongation per inch under strain at elastic limit	do....	.001200
Reduction in diameter at point of rupture	do....	.094
Reduction in area after rupture, per centum of original section		30.6
Position of rupture		.80 inch from neck, taking an oblique course across the bar.
Character of broken surface		dull smoky.

Elongation of inch sections: .12 inch, .12 inch, .15 inch, .18 inch, .25 inch (.26 inch fractured section).

No. 371.



[Mark on bar, 15; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000217	.000117	0.	....	
3, 750	15, 000	.000367	.000150	0.	....	
5, 000	20, 000	.000533	.000166	0.	....	
5, 250	21, 000	.000567	.000034	....	....	
5, 500	22, 000	.000600	.000033	....	....	
5, 750	23, 000	.000633	.000033	....	....	
6, 000	24, 000	.000667	.000034	....	....	
6, 250	25, 000	.000683	.000016	0.	....	
6, 500	26, 000	.000733	.000050	....	....	
6, 750	27, 000	.000767	.000034	....	....	
7, 000	28, 000	.000800	.000033	....	....	
7, 250	29, 000	.000833	.000033	....	....	
7, 500	30, 000	.000867	.000034	.000017	.000017	
7, 750	31, 000	.000933	.000066	....	....	
8, 000	32, 000	.000983	.000050	....	....	
8, 250	33, 000	.001017	.000034	....	....	
8, 500	34, 000	.001067	.000050	....	....	
8, 750	35, 000	.001100	.000033	.000033	.000016	
9, 000	36, 000	.001133	.000033	....	....	
9, 250	37, 000	.001167	.000034	....	....	
9, 500	38, 000	.001233	.000066	....	....	Elastic limit.
9, 750	39, 000	.003450	.002217	....	....	
10, 000	40, 000	.006883	.003433	.005450	.005417	
10, 250	41, 000	.007333	.000450	....	....	
10, 500	42, 000	.008050	.000717	....	....	
10, 750	43, 000	.008700	.000650	....	....	
11, 000	44, 000	.009367	.000667	....	....	
11, 250	45, 000	.010133	.000766	.008467	.003017	
11, 500	46, 000	.010883	.000750	....	....	
11, 750	47, 000	.011500	.000617	....	....	
12, 000	48, 000	.012700	.001200	....	....	
12, 250	49, 000	.013633	.000933	....	....	
12, 500	50, 000	.014733	.001100	.012717	.004250	
13, 000	52, 000	.016633	.001900	....	....	
13, 500	54, 000	.018050	.001417	....	....	
14, 000	56, 000	.020417	.002367	....	....	
14, 500	58, 000	.022850	.002433	....	....	
15, 000	60, 000	.025000	.002150	....	....	
15, 500	62, 000	.028667	.003667	....	....	
16, 000	64, 000	.030833	.002166	....	....	Micrometer removed.
16, 500	66, 000	.0342	.003367	....	....	
17, 000	68, 000	.0367	.0025	....	....	
17, 500	70, 000	.0417	.0050	....	....	
18, 000	72, 000	.0467	.0050	....	....	
18, 500	74, 000	.0567	.0100	....	....	
19, 000	76, 000	.0633	.0066	....	....	
19, 500	78, 000	.0733	.0100	....	....	
20, 000	80, 000	.0833	.0100	....	....	
20, 450	81, 800	....	....	....	....	Ultimate strength.
16, 000	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

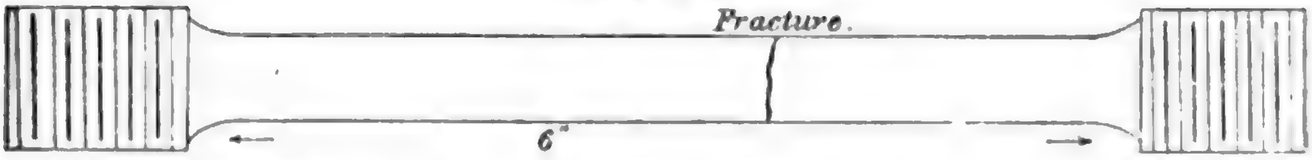
Specific gravity ....
Hardness ....
Tensile strength per square inch of original section ....pounds.. 81, 800
Elastic limit per square inch of original section ....do .. 38, 000
Elongation per inch after rupture ....inch.. 0. 0983
Elongation per inch under strain at elastic limit ....do ... .001233
Reduction in diameter at point of rupture ....do.... .054
Reduction in area after rupture, per centum of original section 18. 3
Position of rupture .... .70 inch from neck.
Character of broken surface .... granular 60 per cent.; dull spongy 40 per centum.

Bar began to fracture at one side, gradually tearing apart. The part fracturing first presents a dull spongy appearance.

An oblique crack opened one-fourth of an inch from the point of fracture.

Elongation of inch sections: .10 inch, .09 inch, .09 inch, .10 inch, .08 inch (.13 inch fractured section).

No. 372.



[Mark on bar, 16; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	Pounds.	Inch.	Inch.	Inch.	Inch.	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000267	.000167	0.	....	
3, 750	15, 000	.000417	.000150	0.	....	
5, 000	20, 000	.000567	.000150	0.	....	
5, 250	21, 000	.000617	.000050	....	....	
5, 500	22, 000	.000650	.000033	....	....	
5, 750	23, 000	.000683	.000033	....	....	
6. 000	24, 000	.000700	.000017	....	....	
6, 250	25, 000	.000733	.000033	.000033	.000033	
6, 500	26, 000	.000783	.000050	....	....	
6, 750	27, 000	.000817	.000034	....	....	
7, 000	28, 000	.000850	.000033	....	....	
7, 250	29, 000	.000883	.000033	....	....	
7, 500	30, 000	.000933	.000050	.000033	0.	
7, 750	31, 000	.000967	.000034	....	....	
8, 000	32, 000	.001000	.000033	....	....	
8, 250	33, 000	.001033	.000033	....	....	
8, 500	34, 000	.001083	.000050	....	....	
8, 750	35, 000	.001100	.000017	.000050	.000017	
9. 000	36, 000	.001133	.000033	....	....	Elastic limit.
9, 250	37, 000	.001200	.000067	....	....	
9, 500	38, 000	.001267	.000067	....	....	
9, 750	39, 000	.001450	.000183	....	....	
10, 000	40, 000	.004500	.003050	.003233	.003183	
10, 250	41, 000	.006683	.002183	....	....	
10, 500	42, 000	.007217	.000534	....	....	
10, 750	43, 000	.008000	.000783	....	....	
11, 000	44, 000	.008583	.000583	....	....	
11, 250	45, 000	.009467	.000884	.007200	.004567	
11, 500	46, 000	.010333	.000866	....	....	
11, 750	47, 000	.010883	.000550	....	....	
12, 000	48, 000	.011800	.000917	....	....	
12, 250	49, 000	.012633	.000833	....	....	
12, 500	50, 000	.013667	.001034	.011700	.003900	
13, 000	52, 000	.015067	.001400	....	....	
13, 500	54, 000	.016983	.001916	....	....	
14, 000	56, 000	.018967	.001984	....	....	
14, 500	58, 000	.021167	.002200	....	....	
15, 000	60, 000	.023333	.002166	....	....	
15, 500	62, 000	.025967	.002634	....	....	
16, 000	64, 000	.028883	.002916	....	....	Micrometer removed.
16, 500	66. 000	.0317	.002817	....	....	
17, 000	68, 000	.0350	.0033	....	....	
17, 500	70, 000	.0383	.0033	....	....	
18, 000	72, 000	.0417	.0034	....	....	
18, 500	74, 000	.0483	.0066	....	....	
19, 000	76, 000	.0550	.0067	....	....	
19, 500	78, 000	.0633	.0083	....	....	
19, 960	79, 840	.0717	.0084	....	....	Ultimate strength.
19, 600	....	....	....	....	....	Load at time of fracture.

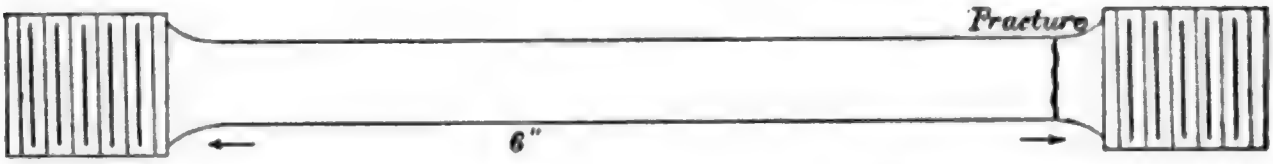
GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	79, 840
Elastic limit per square inch of original section	do....	36, 000
Elongation per inch after rupture	inch..	0. 0683
Elongation per inch under strain at elastic limit	do...	.001133
Reduction in diameter at point of rupture	do....	.034
Reduction in area after rupture, per centum of original section		11. 2
Position of rupture		.75 inch from middle of stem.

Character of broken surface......granular, radiating from a dull spot at the circumference where the fracture began

Elongation of inch sections: .05 inch, .06 inch, .07 inch (.08 inch fractured section), .07 inch, .08 inch

No. 373.



[Mark on bar, 17; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks,
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000117	.000117	.000033	.000033	
2, 500	10, 000	.000317	.000200	.000033	0.	
3, 750	15, 000	.000483	.000166	.000050	.000017	
5, 000	20, 000	.000650	.000167	.000050	0.	
5, 250	21, 000	.000667	.000017	....	....	
5, 500	22, 000	.000717	.000050	....	....	
5, 750	23, 000	.000767	.000050	....	....	
6, 000	24, 000	.000800	.000033	....	....	
6, 250	25, 000	.000833	.000033	.000083	.000033	
6, 500	26, 000	.000867	.000034	....	....	
6, 750	27, 000	.000900	.000033	....	....	
7, 000	28, 000	.000933	.000033	....	....	
7, 250	29, 000	.000967	.000034	....	....	
7, 500	30, 000	.001000	.000033	.000100	.000017	
7, 750	31, 000	.001050	.000050	....	....	
8, 000	32, 000	.001100	.000050	....	....	
8, 250	33, 000	.001117	.000017	....	....	
8, 500	34, 000	.001167	.000050	....	....	
8, 750	35, 000	.001200	.000033	.000117	.000017	
9, 000	36, 000	.001250	.000050	....	....	
9, 250	37, 000	.001283	.000033	....	....	
9, 500	38, 000	.001333	.000050	....	....	
9, 750	39, 000	.001383	.000050	....	....	Elastic limit.
10, 000	40, 000	.002200	.000817	.000950	.000833	
10, 250	41, 000	.003917	.001717	....	....	
10, 500	42, 000	.004783	.000866	....	....	
10, 750	43, 000	.005317	.000534	....	....	
11, 000	44, 000	.006483	.001166	....	....	
11, 250	45, 000	.007083	.000600	.005450	.004500	
11, 500	46, 000	.007750	.000667	....	....	
11, 750	47, 000	.008233	.000483	....	....	
12, 000	48, 000	.009583	.001350	....	....	
12, 250	49, 000	.009883	.000300	....	....	
12, 500	50, 000	.010550	.000667	.008600	.003150	
13, 000	52, 000	.011867	.001317	....	....	
13, 500	54, 000	.013800	.001933	....	....	
14, 000	56, 000	.015917	.002117	....	....	
14, 500	58, 000	.017083	.001166	....	....	
15, 000	60, 000	.019300	.002217	....	....	
15, 500	62, 000	.020967	.001667	....	....	
15, 920	63, 680	....	....	....	....	Ultimate strength.

GENERAL SUMMARY.

Specific gravity		7. 8519
Hardness		17. 35
Tensile strength per square inch of original section	pounds..	63, 680
Elastic limit per square inch of of original section	do	39, 000
Elongation per inch after rupture	inch..	0. 0217
Elongation per inch under strain at elastic limit	do ...	.001383
Reduction in diameter at point of rupture	do....	.004
Reduction in area after rupture, per centum of original section		1. 5
Position of rupture		at the neck.
Character of broken surface		granular.

Elongation of inch sections.... .. .. .02 inch, .02 inch, .02 inch, .02 inch, .02 inch, .03 inch.

No. 374.

[Mark on bar, 18; diameter, .564 inch; sectional area, .25 square inch.]

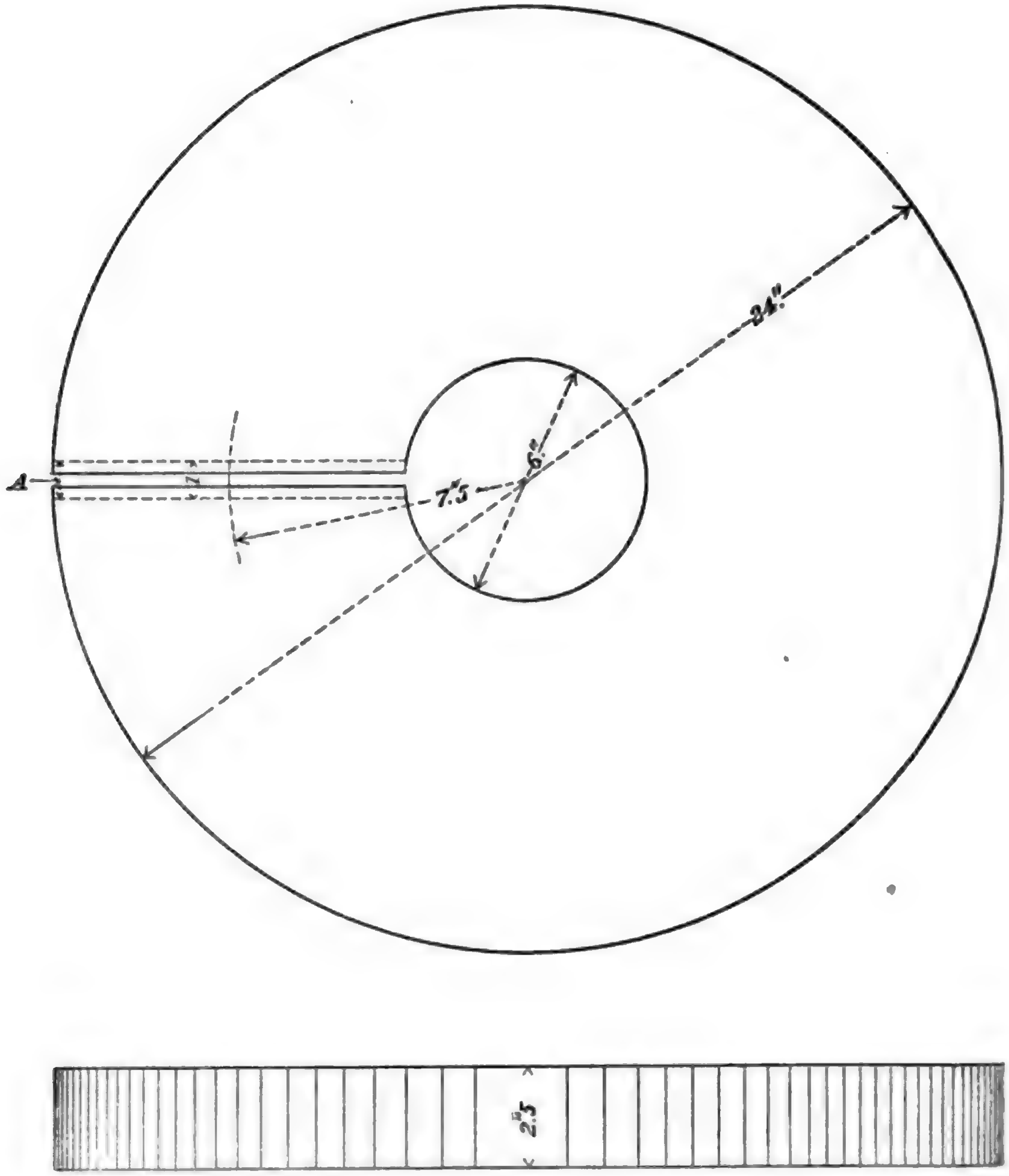
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000117	.000117	0.		
2, 500	10, 000	.000283	000166	0.		
3, 750	15, 000	.000433	.000150	.000017	000017	
5, 000	20, 000	.000583	.000150	.000017	.0	
5, 250	21, 000	.000600	.000017			
5, 500	22, 000	.000633	.000033			
5, 750	23, 000	.000667	.000034			
6, 000	24, 000	.000700	.000033			
6, 250	25, 000	.000733	.000033	.000050	.000033	
6, 500	26, 000	.000800	.000067			
6, 750	27, 000	.000833	.000033			
7, 000	28, 000	.000867	.000034			
7, 250	29, 000	.000883	.000016			
7, 500	30, 000	.000933	.000050	.000067	.000017	
7, 750	31, 000	.000967	.000034			
8, 000	32, 000	.001017	.000050			
8, 250	33, 000	.001050	.000033			
8, 500	34, 000	.001100	.000050			
8, 750	35, 000	.001133	.000033	.000100	.000033	
9, 000	36, 000	.001150	.000017			Elastic limit.
9, 250	37, 000	.001217	.000067			
9, 500	38, 000	.001383	.000166			
9, 750	39, 000	.002383	.001000			
10, 000	40, 000	.003467	.001084	.002133	.002033	
10, 250	41, 000	.004300	.000833			
10, 500	42, 000	.005300	.001000			
10, 750	43, 000	.006250	.000950			
11, 000	44, 000	.007133	.000883			
11, 250	45, 000	.007550	.000417	.005967	.003834	
11, 500	46, 000	.008183	.000633			
11, 750	47, 000	.008967	.000784			
12, 000	48, 000	.009833	.000866			
12, 250	49, 000	.010633	.000800			
12, 500	50, 000	.011483	.000850	.009533	.003566	
13, 000	52, 000	.012833	.001350			
13, 500	54, 000	.014500	.001667			
14, 000	56, 000	.016033	.001533			
14, 500	58, 000	.018367	.002334			
15, 000	60, 000	.020317	.001950			Micrometer removed.
15, 500	62, 000	.0233	.002983			
16, 000	64, 000	.0258	.0025			
16, 500	66, 000	.0300	.0042			
17, 000	68, 000	.0317	.0017			
17, 500	70, 000	.0342	.0025			
18, 000	72, 000	.0383	.0041			
18, 500	74, 000	.0417	.0034			
19, 000	76, 000	.0450	.0033			Snapping sounds.
19, 500	78, 000	.0533	.0083			
19, 800	79, 200					Ultimate strength.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	79 200
Elastic limit per square inch of original section	do	36, 000
Elongation per inch after rupture	inch	0. 0517
Elongation per inch under strain at elastic limit	do	.001150
Reduction in diameter at point of rupture		
Reduction in area after rupture, per centum of original section		not obtained.
Position of rupture		at the neck.
Character of broken surface		granular.

Elongation of inch sections: .04 inch, .06 inch, .06 inch, .06 inch, .04 inch (.05 inch fractured section).

Initial tension of ring.



The initial tension ring was clamped along a radius to the bed of a planer, and a radial cut made with a square-nose tool (.336 inch wide), in the prolongation of the clamped radius, commencing at the interior, and cutting towards the exterior. Very light cuts were made.

One-half inch from the center line of the cut, and on each side of the same, three sets of points were taken—one near the exterior, another near the interior, and a third midway between. The diameters were, respectively, 24 inches, 6 inches, and 15 inches.

When the remaining web was about one thirty-second of an inch thick, a slight sound was heard, but no break could be discovered. The distance between the exterior points A was 1.01 inches. The cutting was continued until the web was separated; whether torn by the strain or forced off by the tool could not be ascertained, as the edges were rough and less than .01 inch thick.

The measurements gave 1.032 inches, 1 010 inches, and 1.020 inches.

Deducting 1 inch from the circumference and dividing .032 inch by the same, obtain as the change per inch .00043 inch.

A mean of samples 14, 15, and 16 gave, under a strain of 15,660 pounds, a stretch of .00043 inch per inch.

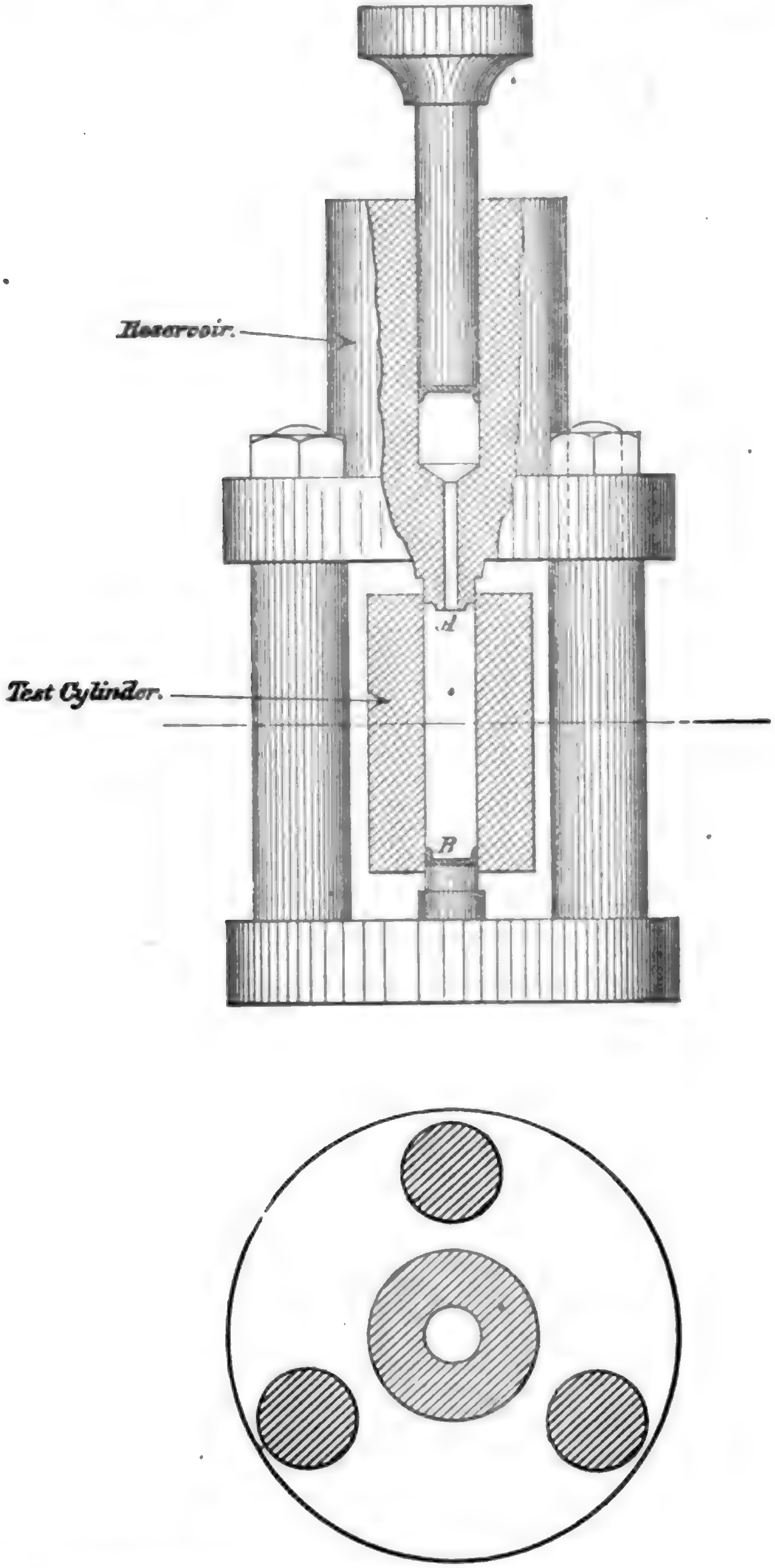
The top of the cut at the exterior measured .372 inch, showing a contraction of .036 inch; dividing this by the circumference less .336 inch, gave as the change per inch .00047 inch.

The bottom of the cut at the exterior measured .3653 inch, showing a contraction of .0293 inch; this corresponded to a change of .00038 inch per inch.

A mean of samples 14, 15, and 16 gave a stretch per inch of .00047 inch under a strain of 17,170 pounds, and .00038 inch under a strain of 14,000 pounds.

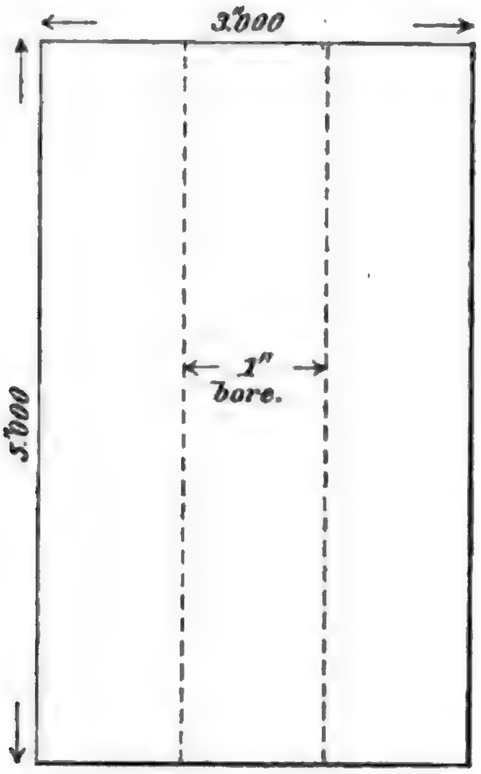
The initial tension of the ring may, therefore, be taken as 16,000 pounds.

Attachment for tangential tests showing test cylinder in position.



TANGENTIAL TESTS.—(Employing attachment as shown by blue print.)

Test cylinder and reservoir charged with water. Length of bore o[f] cylinder exposed to internal pressure 4.55 inches, which includes space occupied by leather packings, copper checks .09 inch thick at end A, and copper checks .18 inch thick at end B.



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[f] Mark on cylinder, 25; diameter of reservoir chamber, 1.17 inches; sectional area, 1.075 square inches.

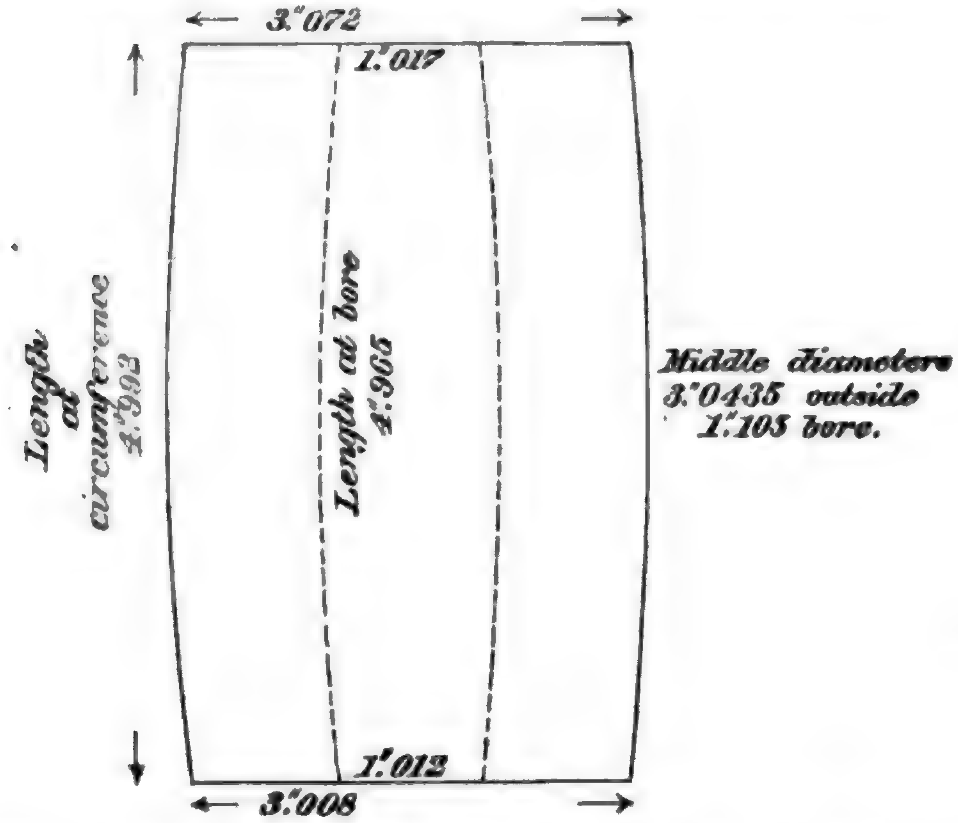
Applied loads on piston of reservoir.		Enlargement of middle diameter of cylinder.	Remarks.
Total.	Per square inch.		
Pounds.	*Pounds.*	*Inch.*	
1, 075	1, 000	0.	Initial load.
32, 250	80, 000	....	
1, 075	1, 000	0.	
58, 750	50, 000	....	
1, 075	1, 000	.0014	
93, 000	86, 512	....	Maximum load reached.
1, 075	1, 000	.0435	

While loads were applied, the cylinder was covered with canvas, which was removed after each loading to admit of measuring the distortion in diameter while under the initial load.

After the enlargement caused by 86,512 pounds per square inch had been determined, the cylinder was subjected to a pressure of 30,000 pounds per square inch uncovered.

There was no evidence of porosity under this latter pressure.

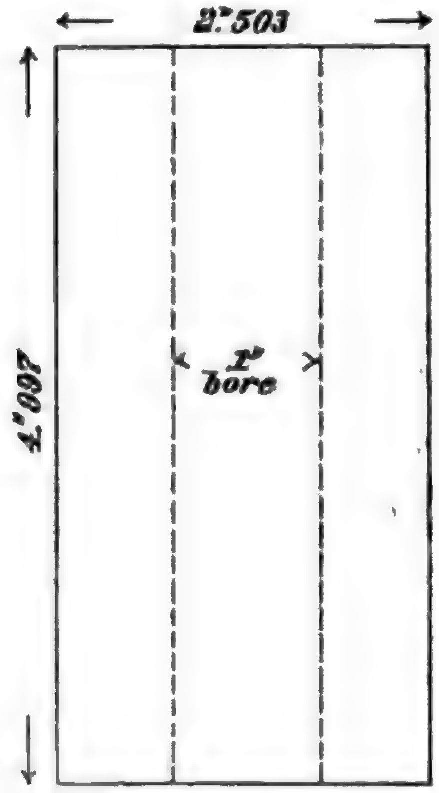
Dimensions of cylinder after having been loaded with 86,512 pounds per square inch.


3".072
1".017
Length at circumference 4".993
Length at bore 4".965
Middle diameters 3".0435 outside 1".105 bore.
1".012
3".008

A crack one-fourth of an inch long was developed in the bore 1.8 inches from end.

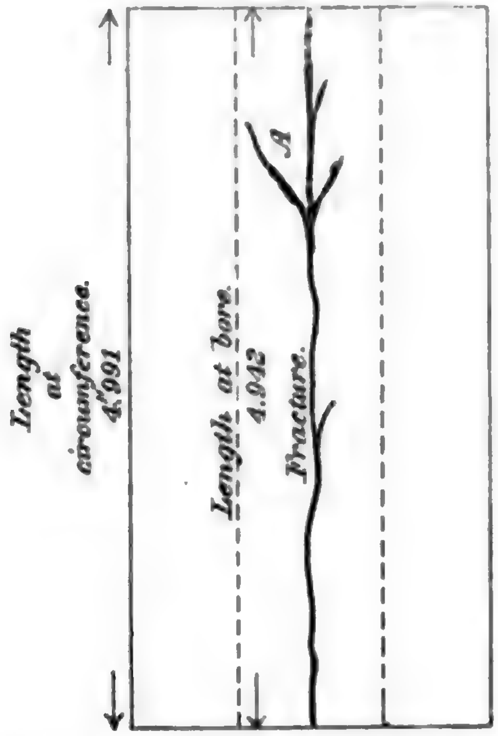
Four spongy spots of metal at one end of cylinder, varying in diameter from one-sixteenth to one-fourth of an inch.

[Mark on cylinder, 26.]



Applied loads on piston of reservoir.		Enlargement of middle diameter of cylinder.	Remarks.
Total.	Per square inch.		
Pounds.	*Pounds.*	*Inch.*	
1, 075	1, 000	0.	Initial load.
10, 750	10, 000	. 002	
21, 500	20, 000	. 004	
32, 250	30, 000	. 0045	
1, 075	1, 000	0.	
37, 625	35, 000	....	
1, 075	1, 000	. 0003	
43, 000	40, 000	....	
1, 075	1, 000	. 003+	
48, 375	45, 000	....	
1, 075	1, 000	. 0045	
53, 750	50, 000	....	
1, 075	1, 000	. 009	
59, 125	55, 000	....	
1, 075	1, 000	. 016	
64, 500	60, 000	....	
1, 075	1, 000	. 023	
78, 200	72, 744	....	Bursting pressure.

The cylinder burst into two pieces. The lines of fracture were nearly parallel to the axis of the cylinder, and separated it into parts which weighed 3 pounds 3 ounces, and 2 pounds 10½ ounces, respectively.



The line of fracture on one side, A, as shown by the sketch, was irregular, tending to branch out at one end.

The fractured surface was granular and flaky, radiating from the center. Two small blow-holes are in the plane of fracture, one is one-half inch from the middle of the length of the cylinder, at the bore, and one three-fourths of an inch from the middle at the circumference.

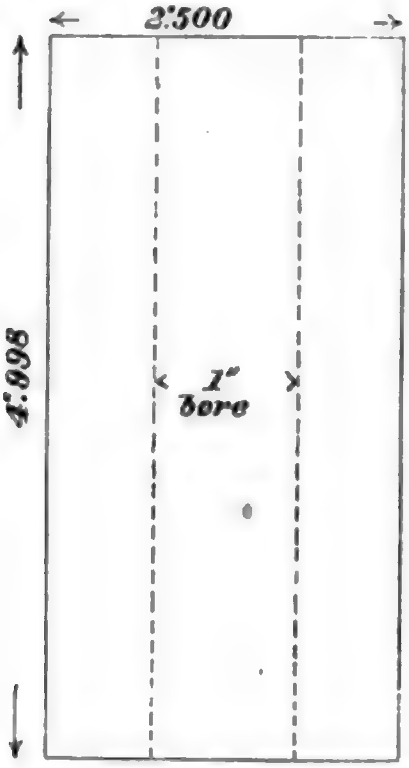
It is thought this side was the first to fracture.

The fracture of the opposite side was more direct from end to end. Its appearance was granular, radiating from a point at the bore, midway its length.

The walls of the cylinder were reduced in thickness .05 inch at the middle. Maximum diameter of bore, 1.15 inches.

The copper checks were expanded to 1.04 inches diameter at lower end of cylinder, B, and 1.03 inches diameter at upper end, A.

[Mark on cylinder, 27]



Five spongy spots of metal were observed in finishing this cylinder. All turned out except one. Maximum size of spots .20 by .20 inch.

Applied loads on piston of reservoir.		Enlargement of middle diameter of cylinder.	Remarks.
Total.	Per square inch.		
Pounds.	*Pounds.*	*Inch.*	
1, 075	1, 000	0.	Initial load.
10, 750	10, 000	0.	
21, 500	20, 000	.0005	
32, 250	30, 000	.0005	
37, 625	35, 000	....	
1, 075	1, 000	.001	
43, 000	40, 000	....	
1, 075	1, 000	.002	
48, 375	45, 000	....	
1, 075	1, 000	.005	
53, 750	50, 000	....	
1, 075	1, 000	.009	
59, 125	55, 000	....	
1, 075	1, 000	.013	
64, 500	60, 000	....	
1, 075	1, 000	.019	
77, 500	72, 093	....	Bursting pressure.

The cylinder burst into two pieces. The lines of fracture were nearly parallel to the axis of the cylinder, and separated it into parts weighing 3 pounds 6½ ounces, and 2 pounds 7 ounces, respectively.

The fractures were granular. One fractured surface radiating from points along the bore. It is thought that the fracture occurred first in this surface.

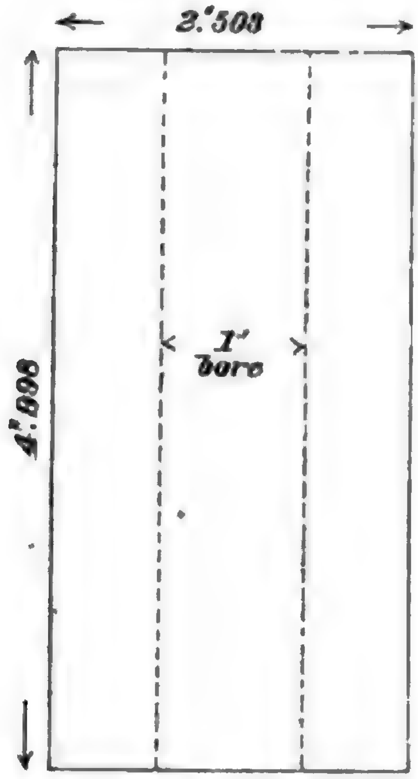
The opposite surface had two distinct centers of radiation, situated 1 inch and 1½ inches, respectively, from the ends of the cylinder.

In the larger fragment, a longitudinal seam was opened extending from one end along the bore a distance of 2½ inches, and .55 inch deep.

The copper checks were enlarged to 1.02 inches diameter at the lower end of the cylinder, B, and to 1.03 inches diameter at the upper end, A.

Minimum thickness of walls, .71 inch.

[Mark on cylinder, 28.]

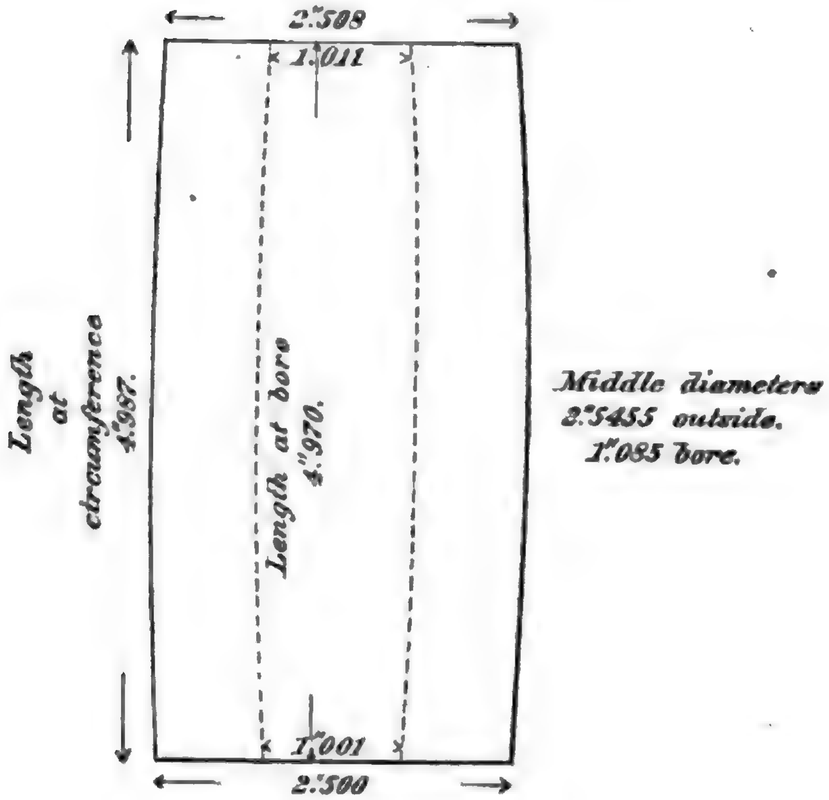


Applied loads on piston of reservoir.		Enlargement of middle diameter of cylinder.	Remarks.
Total.	Per square inch.		
Pounds.	*Pounds.*	*Inch.*	
1, 075	1, 000	0.	Initial load.
10, 750	10, 000	. 0005	
21. 500	20, 000	. 0005	
32, 250	30, 000	. 0005	
37, 625	35, 000	. 0005	
1, 075	1. 000	0.	
43, 000	40, 000	....	
1, 075	1, 000	.0005	
48, 375	45, 000	....	
1, 075	1, 000	. 0015	
53, 750	50, 000	....	
1, 075	1, 000	. 0065	
59, 125	55, 000	....	
1, 075	1. 000	. 0095	
64, 500	60, 000	....	
1, 075	1, 000	. 0145	
80, 500	74, 884	....	Maximum pressure reached.
0	0	. 0425	

The hydraulic pressure was gradually increased and sustained by the cylinder until 74,884 pounds per square inch on the piston of the reservoir was reached, when suddenly the pressure fell, unaccompanied, however, by any sounds of rupture.

Upon removal from the testing machine there were found four lines of rupture in the surface of the bore, from one-half to 1¼ inches long. On the exterior surface a crack .10 inch long was developed; this was in that part of the cylinder containing the interior cracks, but not directly opposite.

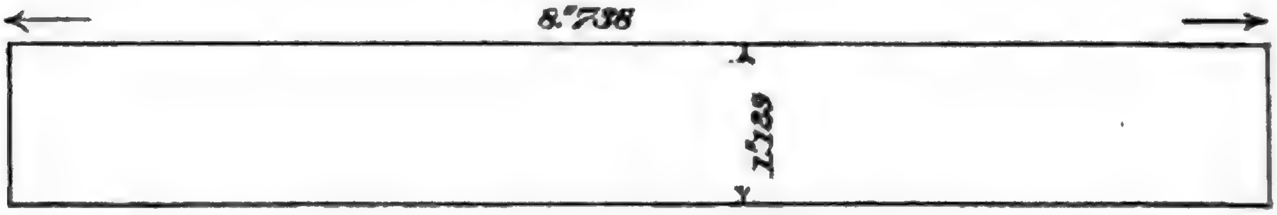
Form of specimen after test.


2".508
1".011
Length at circumference 4".987.
Length at bore 4".970.
Middle diameters 2".5455 outside. 1".085 bore.
1".001
2".500

TESTS BY COMPRESSION: 4 CAST-STEEL SPECIMENS FROM TRIAL CYLINDER; 2 CAST-STEEL SPECIMENS FOR TRANSVERSE RESISTANCE.

August 23, 1884.

No. 401.



[Mark on bar, 19; diameter, 1.129 inches; sectional area, 1.00 square inch.]

Applied load		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0.	0.	0.	0.	Initial load.
5,000	5,000	.000100	.000100	....	....	
10,000	10,000	.000250	.000150	....	....	
15,000	15,000	.000417	.000167	....	....	
20,000	20,000	.000600	.000183	.000017	.000017	
21,000	21,000	.000617	.000017	....	....	
22,000	22,000	.000667	.000050	....	....	
23,000	23,000	.000717	.000050	....	....	
24,000	24,000	.000767	.000050	....	....	
25,000	25,000	.000800	.000033	.000033	.000016	
26,000	26,000	.000833	.000033	....	....	
27,000	27,000	.000867	.000034	....	....	
28,000	28,000	.000900	.000033	....	....	
29,000	29,000	.000933	.000033	....	....	
30,000	30,000	.000967	.000034	.000050	.000017	
31,000	31,000	.000983	.000016	....	....	
32,000	32,000	.001033	.000050	....	....	
33,000	33,000	.001067	.000034	....	....	
34,000	34,000	.001100	.000033	....	....	
35,000	35,000	.001133	.000033	.000067	.000017	
36,000	36,000	.001183	.000050	....	....	
37,000	37,000	.001217	.000034	....	....	
38,000	38,000	.001250	.000033	....	....	
39,000	39,000	.001283	.000033	....	....	Elastic limit.
40,000	40,000	.001367 .003500	.000084 .002133	.000083	.000016	 Rapid deflection.
41,000	41,000	.005833	.002333	....	....	
42,000	42,000	.007000	.001167	....	....	
43,000	43,000	.007917	.000917	....	....	
44,000	44,000	.008417	.000500	....	....	
45,000	45,000	.008917	.000500	....	....	
46,000	46,000	.009467	.000550	....	....	
47,000	47,000	.010100	.000633	....	....	
48,000	48,000	.010667	.000567	....	....	
49,000	49,000	.011333	.000666	....	....	
50,000	50,000	.012067	.000734	.010167	.010084	
67,400	67,400	....	....	....	....	Ultimate strength.
60,000	60,000	....	....	....	....	Load sustained when test was discontinued.

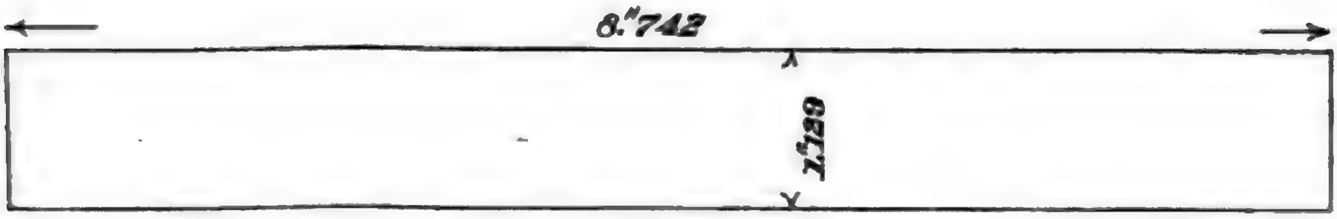
Failed by triple flexure. Middle deflection after the test, .45 inch.
Blow-hole, .05 inch, diameter, .06 inch from end of bar.

GENERAL SUMMARY.

Ultimate strength per square inch of original section	pound..	67,400
Elastic limit per square inch of original section	do....	39,000
Compression per inch under strain at elastic limit	inch..	0.001283

There were two blow-holes in sight when the bar was 1⅜ inches diameter. One, .20 by .10 inch; 2¼ inches from end, nearly turned out; one, .10 by .10 inch, did not turn out when bar was brought to finished size. Numerous small pin-holes in sight.

No. 402.



[Mark on bar, 20; diameter, 1.129 inches; sectional area, 1.00 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0.	0.	0.	0.	Initial load.
5, 000	5, 000	.000133	.000133	....	....	
10, 000	10, 000	.000300	.000167	.000017	.000017	
15, 000	15, 000	.000433	.000133	.000017	0.	
20, 000	20, 000	.000633	.000200	.000033	.000016	
21, 000	21, 000	.000667	.000034	....	....	
22, 000	22, 000	.000700	.000033	....	....	
23, 000	23, 000	.000750	.000050	....	....	
24, 000	24, 000	.000783	.000033	....	....	
25, 000	25, 000	.000817	.000034	.000050	.000017	
26, 000	26, 000	.000833	.000016	....	....	
27, 000	27, 000	.000867	.000034	....	....	
28, 000	28, 000	.000900	.000033	....	....	
29, 000	29, 000	.000933	.000033	....	....	
30, 000	30, 000	.000967	.000034	.000067	.000017	
31, 000	31, 000	.001017	.000050	....	....	
32, 000	32, 000	.001050	.000033	....	....	
33, 000	33, 000	.001083	.000033	....	....	
34, 000	34, 000	.001117	.000034	....	....	
35, 000	35, 000	.001150	.000033	.000100	.000033	
36, 000	36, 000	.001200	.000050	....	....	
37, 000	37, 000	.001233	.000033	....	....	
38, 000	38, 000	.001300	.000067	....	....	
39, 000	39, 000	.001350	.000050	....	....	Elastic limit.
40, 000	40, 000	....	....	....	....	Sustained momentarily, then pressure fell, accompanied by deflection of the bar.
38, 000	38, 000	.002217	.000867	....	....	
38, 500	38, 500	.002400	.000183	....	....	
39, 000	39, 000	.002767	.000367	....	....	
39, 500	39, 500	.003550	.000783	....	....	
40, 000	40, 000	.004600	.001050	.003267	.003167	
41, 000	41, 000	.005950	.001350	....	....	
42, 000	42, 000	.006683	.000733	....	....	
43, 000	43, 000	.007450	.000767	....	....	
44, 000	44, 000	.008067	.000617	....	....	
45, 000	45, 000	.008717	.000650	.007067	.003800	
46, 000	46, 000	.009250	.000533	....	....	
47, 000	47, 000	.009750	.000500	....	....	
48, 000	48, 000	.010250	.000500	....	....	
49, 000	49, 000	.010867	.000617	....	....	
50, 000	50, 000	.011500	.000633	.009667	.002600	
65, 980	65, 980	....	....	....	....	Ultimate strength.
50, 000	50, 000	....	....	....	....	Load sustained when test was discontinued.

Failed by triple flexure. Middle deflection .68 inch after the test.
Metal ruptured in vicinity of blow-hole at middle of bar.

GENERAL SUMMARY.

Ultimate strength per square inch of original section .... pounds.. 65, 980
Elastic limit per square inch of original section .... do .. 39, 000
Compression per inch under strain at elastic limit .... inch.. 0. 001350

No. 403.

[Mark on bar, 21; diameter, 1.129 inches; sectional area, 1.00 square inch.]

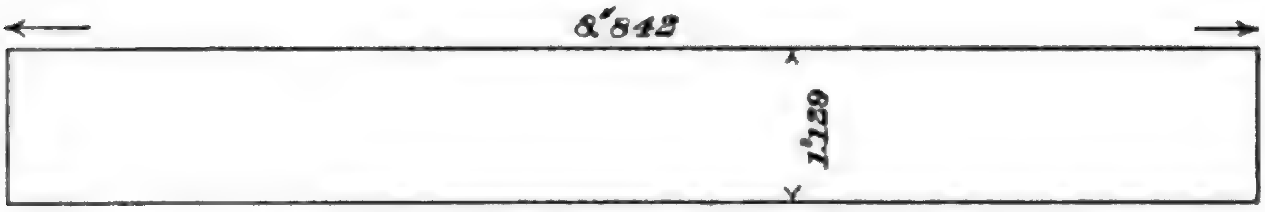
Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0.	0.	0.	0.	Initial load.
5, 000	5, 000	.000150	.000150	.000017	.000017	
10, 000	10, 000	.000300	.000150	.000017	0.	
15, 000	15, 000	.000483	.000183	.000050	.000033	
20, 000	20, 000	.000667	.000184	.000067	.000017	
21, 000	21, 000	.000683	.000016	....	....	
22, 000	22, 000	.000733	.000050	....	....	
23, 000	23, 000	.000767	.000034	....	....	
24, 000	24, 000	.000800	.000033	....	....	
25, 000	25, 000	.000833	.000033	.000067	0.	
26, 000	26, 000	.000867	.000034	....	....	
27, 000	27, 000	.000917	.000050	....	....	
28, 000	28, 000	.000950	.000033	....	....	
29, 000	29, 000	.000967	.000017	....	....	
30, 000	30, 000	.001000	.000033	.000083	.000016	
31, 000	31, 000	.001033	.000033	....	....	
32, 000	32, 000	.001067	.000034	....	....	
33, 000	33, 000	.001100	.000033	....	....	
34, 000	34, 000	.001133	.000033	....	....	
35, 000	35, 000	.001167	.000034	.000083	0.	
36, 000	36, 000	.001200	.000033	....	....	
37, 000	37, 000	.001233	.000033	....	....	
38, 000	38, 000	.001267	.000034	....	....	
39, 000	39, 000	.001300	.000033	....	....	
40, 000	40, 000	.001333	.000033	.000100	.000017	
41, 000	41, 000	.001367	.000034	....	....	
42, 000	42, 000	.001417	.000050	....	....	
43, 000	43, 000	.001450	.000033	....	....	
44, 000	44, 000	.001467	.000017	....	....	
45, 000	45, 000	.001517	.000050	.000133	.000033	Elastic limit.
46, 000	46, 000	.001583	.000066	....	....	
47, 000	47, 000	.001650	.000067	....	....	
48, 000	48, 000	.004933	.003283	....	....	Rapid deflection.
49, 000	49, 000	.005617	.000684	....	....	
50, 000	50, 000	.006167	.000550	.004317	.004184	
74, 800	74, 800	....	....	....	....	Ultimate strength.
50, 000	50, 000	....	....	....	....	Load sustained when test was discontinued.

Failed by triple flexure. Middle deflection .80 inch after the test.

GENERAL SUMMARY.

Ultimate strength per square inch of original section	pounds..	74, 800
Elastic limit per square inch of original section	do....	45, 000
Compression per inch under strain at elastic limit	inch..	0. 001517

No. 404.



[Mark on bar, 22; diameter, 1.129 inches; sectional area, 1.00 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	500	0.	0.	0.	0.	Initial load.
5,000	5,000	.000133	.000133	0.		
10,000	10,000	.000317	.000184	.000067	.000067	
15,000	15,000	.000467	.000150	.000083	.000016	
20,000	20,000	.000633	.000166	.000063	0.	
21,000	21,000	.000667	.000034			
22,000	22,000	.000717	.000050			
23,000	23,000	.000767	.000050			
24,000	24,000	.000800	.000033			
25,000	25,000	.000817	.000017	.000100	.000017	
26,000	26,000	.000833	.000016			
27,000	27,000	.000850	.000017			
28,000	28,000	.000900	.000050			
29,000	29,000	.000950	.000050			
30,000	30,000	.001000	.000050	.000117	.000017	
31,000	31,000	.001017	.000017			
32,000	32,000	.001067	.000050			
33,000	33,000	.001100	.000033			
34,000	34,000	.001133	.000033			
35,000	35,000	.001150	.000017	.000117	0.	
36,000	36,000	.001167	.000017			
37,000	37,000	.001217	.000050			
38,000	38,000	.001250	.000033			
39,000	39,000	.001300	.000050			
40,000	40,000	.001333	.000033	.000117	0.	
41,000	41,000	.001367	.000034			
41,350	41,350	.001400 .001883	.000033 .000483			Elastic limit.
41,500	41,500	.002333	.000450			Perceptible deflection.
42,000	42,000	.002750	.000417			
43,000	43,000	.003650	.000900			
44,000	44,000	.004133	.000483			
45,000	45,000	.004550	.000417	.002900	.002783	
46,000	46,000	.004833	.000283			
47,000	47,000	.005200	.000367			
48,000	48,000	.005600	.000400			
49,000	49,000	.006067	.000467			
50,000	50,000	.006433	.000366	.004633	.001733	
65,700	65,700					Ultimate strength.
50,000	50,000					Load sustained when test was discontinued.

Failed by triple flexure. Middle deflection .82 inch after the test.
Spongy spot 1¼ inches from end (one-fourth by one-sixteenth inch).

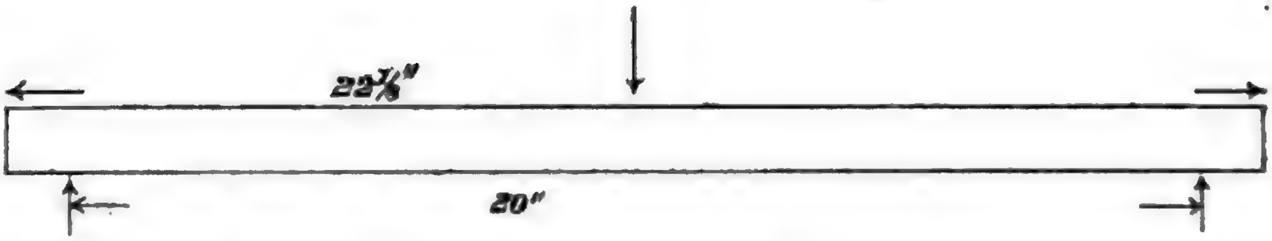
GENERAL SUMMARY.

Ultimate strength per square inch of original section	pounds..	65,700
Elastic limit per square inch of original section	do....	41,350
Compression per inch under strain at elastic limit	inch..	0.001400

Several small blow-holes were found on one side of bar, many of which turned out in reducing specimen to finished size.

TRANSVERSE TEST.

No. 3.



[Mark on bar, 23; diameter, 1.129 inches; loaded at the middle; end supports 20 inches apart.]

Applied loads.		Deflection.	Successive deflection.	Deflection set.	Successive deflection set.	Remarks.
Total.	Maximum fiber strain.					
Pounds.	*Pounds.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	
0	0	0.	0.	0.	0.	
56	2, 000	. 0040	. 0040	....	....	
113	4, 000	. 0083	. 0043	....	....	Minimum fiber strain computed by the formula $R = \frac{P\,v}{\pi 7^{\cdot 3}}$
169	6, 000	. 0119	. 0036	....	....	
226	8, 000	. 0160	. 0041	....	....	
282	10, 000	. 0195	. 0035	. 0001	. 0001	
339	12, 000	. 0235	. 0040	....	....	
395	14, 000	. 0275	. 0040	....	....	
452	16, 000	. 0315	. 0040	....	....	
508	18, 000	. 0349	. 0034	....	....	
565	20, 000	. 0385	. 0036	. 0006	. 0005	
621	22, 000	. 0418	. 0033	....	....	
678	24, 000	. 0452	. 0034	....	....	
734	26, 000	. 0488	. 0036	....	....	
791	28, 000	. 0521	. 0033	....	....	
847	30, 000	. 0560	. 0039	. 0009	. 0003	
904	32, 000	. 0597	. 0037	....	....	
960	34, 000	. 0635	. 0038	....	....	
1, 017	36, 000	. 0673	. 0038	....	....	
1, 073	38, 000	. 0708	. 0035	....	....	
1, 130	40, 000	. 0747	. 0039	. 0017	. 0008	
1, 186	42, 000	. 0795	. 0048	....	....	
1, 243	44, 000	. 0829	. 0034	....	....	
1, 299	46, 000	. 0867	. 0038	....	....	
1, 356	48, 000	. 0908	. 0041	....	....	
1, 412	50, 000	. 0945	. 0037	. 0027	. 0010	
1, 468	52, 000	. 0994	. 0049	....	....	
1, 525	54, 000	. 1038	. 0044	....	....	
1, 581	56, 000	. 1080	. 0042	....	....	Elastic limit.
1, 638	58, 000	. 1131	. 0051	....	....	
1, 694	60, 000	. 1190	. 0059	. 0075	. 0048	
1, 751	62, 000	. 1270	. 0080	....	....	
1, 807	64, 000	. 1340	. 0070	....	....	
1, 864	66, 000	. 1468	. 0128	....	....	
1, 920	68, 000	. 1662	. 0194	....	....	
1, 977	70, 000	. 1913	. 0251	. 0547	. 0472	
2, 033	72, 000	. 2201	. 0288	....	....	
2, 090	74, 000	. 2497	. 0296	....	....	
2, 146	76, 000	. 2850	. 0353	....	....	
2, 203	78, 000	. 3314	. 0464	....	....	
2, 259	80, 000	. 3740	. 0426	....	....	
2, 316	82, 000	. 40	. 0260	....	....	
2, 372	84, 000	. 45	. 05	....	....	
2, 429	86, 000	. 51	. 06	....	....	
2, 485	88, 000	. 55	. 04	....	....	
2, 542	90, 000	. 61	. 06	....	....	
2, 598	92, 000	. 68	. 07	....	....	
2, 654	94, 000	. 75	. 07	....	....	
2, 711	96, 000	. 78	. 03	....	....	
2, 768	98, 000	. 84	. 06	....	....	
2, 824	100, 000	. 91	. 07	....	....	
2, 880	102, 000	. 97	. 06	....	....	
2, 937	104, 000	1. 04	. 07	....	....	
2, 993	106, 000	1. 11	. 07	....	....	
3, 050	108, 000	1. 20	. 09	....	....	
3, 106	110, 000	1. 29	. 09	....	....	
3, 163	112, 000	1. 37	. 08	....	....	
3, 219	114, 000	1. 46	. 09	....	....	
3, 276	116, 000	1. 55	. 09	....	....	

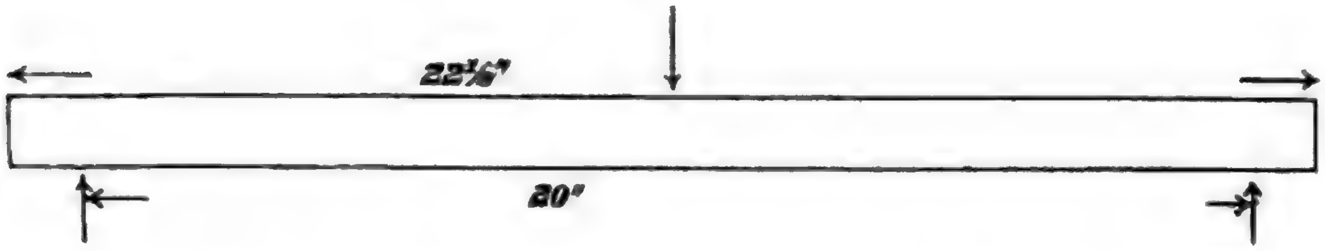
Applied loads.		Deflection.	Successive deflection.	Deflection set.	Successive deflection set.	Remarks.
Total.	Maximum fiber strain.					
Pounds.	*Pounds.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	
3, 332	118, 000	1. 64	. 09	....	....	
3, 389	120, 000	1. 73	. 09	....	....	
3, 445	122, 000	1. 83	. 10	....	....	
3, 502	124, 000	1. 98	. 15	....	....	
3, 558	126, 000	2. 11	. 18	....	....	
3. 615	128, 000	2. 33	. 22	....	....	
3, 671	130, 000	2. 46	. 13	....	....	
3, 728	132, 000	2. 60	....	....	....	
3, 784	134, 000	2. 88	....	....	....	
3, 841	136, 000	3. 30	....	....	....	
3, 860	136, 680	4. 00	....	....	....	Specimen drew off the end bearings.

The metal on the tension side opposite the middle bearing showed incipient fractures.

Permanent deflection, 4.20 inches.

A small blow-hole was found at the middle of the length of bar, which turned out before finished diameter was reached.

No. 4.



[Mark on bar, 24; diameter, 1.129 inches; loaded at the middle; end supports 20 inches apart.]

Applied loads.		Deflection.	Successive deflection.	Deflection set.	Successive deflection set.	Remarks.
Total.	Maximum fiber strain.					
Pounds.	*Pounds.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	
0	0	0.	0.	0.	0.	
56	2, 000	. 0040	. 0040	....	....	
113	4, 000	. 0081	. 0041	....	....	
169	6, 000	. 0120	. 0039	....	....	
226	8, 000	. 0160	. 0040	....	....	
282	10, 000	. 0194	. 0034	. 0002	. 0002	
339	12, 000	. 0240	. 0046	....	....	
395	14, 000	. 0273	. 0033	....	....	
452	16, 000	. 0310	. 0037	....	....	
508	18, 000	. 0349	. 0039	....	....	
565	20, 000	. 0388	. 0039	. 0003	. 0001	
621	22, 000	. 0430	. 0042	....	....	
678	24, 000	. 0468	. 0038	....	....	
734	26, 000	. 0510	. 0042	....	....	
791	28, 000	. 0545	. 0035	....	....	
847	30, 000	. 0578	. 0033	. 0009	. 0006	
904	32, 000	. 0617	. 0039	....	....	
960	34, 000	. 0651	. 0034	....	....	
1, 017	36, 000	. 0688	. 0037	....	....	
1, 073	38, 000	. 0723	. 0035	....	....	
1, 130	40, 000	. 0765	. 0042	. 0011	. 0002	
1, 186	42, 000	. 0811	. 0046	....	....	
1, 243	44, 000	. 0851	. 0040	....	....	
1, 299	46, 000	. 0888	. 0037	....	....	
1, 356	48, 000	. 0929	. 0041	....	....	
1, 412	50, 000	. 0968	. 0039	. 0024	. 0013	
1, 468	52, 000	. 1010	. 0042	....	....	
1, 525	54, 000	. 1052	. 0042	....	....	
1, 581	56, 000	. 1093	. 0041	....	....	Elastic limit.

Applied loads.		Deflection.	Successive deflection.	Deflection set.	Successive deflection set.	Remarks.
Total.	Maximum fiber strain.					
Pounds.	*Pounds.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*	
1, 638	58, 000	.1142	.0049	....	....	
1, 694	60, 000	.1198	.0056	.0060	.0036	
1, 751	62, 000	.1260	.0062	....	....	
1, 807	64, 000	.1325	.0065	....	....	
1, 864	66, 000	.1436	.0111	....	....	
1, 920	68, 000	.1580	.0144	....	....	
1, 977	70, 000	.1857	.0277	.0470	.0410	
2, 033	72, 000	.2198	.0341	....	....	
2, 090	74, 000	.2539	.0341	....	....	
2, 146	76, 000	.3000	.0461	....	....	
2, 203	78, 000	.3506	.0506	....	....	
2, 259	80, 000	.3942	.0436	....	....	
2, 316	82, 000	.45	.0558	....	....	
2, 372	84, 000	.50	.05	....	....	
2, 429	86, 000	.55	.05	....	....	
2, 485	88, 000	.60	.05	....	....	
2, 542	90, 000	.67	.07	....	....	
2, 598	92, 000	.73	.06	....	....	
2, 654	94, 000	.79	.06	....	....	
2, 711	96, 000	.85	.06	....	....	
2, 768	98, 000	.94	.09	....	....	
2, 824	100, 000	1. 0	.06	....	....	
2, 880	102, 000	1. 08	.08	....	....	
2, 937	104, 000	1. 15	.07	....	....	
2, 993	106, 000	1. 24	.09	....	....	
3, 050	108, 000	1. 33	.09	....	....	
3, 106	110, 000	1. 41	.08	....	....	
3, 163	112, 000	1. 51	.10	....	....	
3, 219	114, 000	1. 60	.09	....	....	
3, 276	116, 000	1. 75	.15	....	....	
3, 332	118, 000	1. 83	.08	....	....	
3, 389	120, 000	1. 98	.15	....	....	
3, 445	122, 000	2. 15	.17	....	....	
3, 502	124, 000	2. 3	.15	....	....	
3, 558	126, 000	2. 51	.21	....	....	
3, 615	128, 000	2. 73	.22	....	....	
3, 671	130, 000	3. 07	.34	....	....	
3, 728	132, 000	3. 87	.80	....	....	Maximum load reached.

When the deflection reached 5.06 inches the specimen drew off the end bearings.
No indications of rupture of the metal.
Permanent deflection 4.46 inches.

Summary statement of trial cylinder, cast steel, from Otis Iron and Steel Company.

TENSILE TESTS.

Marks.		Specific gravity.	Hardness.	Tensile strength per square inch of original section.	Elastic limit per square inch of original section.	Ultimate elongation.	Elongation per inch at elastic limit.	Ultimate reduction in diameter.	Reduction in area after rupture.
				Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Per ct.*
Top.	1. Tangential, outside	....	....	60, 880	39, 000	0. 02	. 001267	. 014	5. 0
	2. Tangential, middle	....	....	73, 120	43, 000	0. 02	. 001383	. 014	5. 0
	3. Tangential, inside	....	....	97, 440	48, 000	0. 0383	. 001567	. 034	11. 8
Bottom.	4. Tangential, inside	....	....	86, 400	35, 000	0. 1483	. 001100	. 084	27. 6
	5. Tangential, middle	....	....	86, 000	35, 000	0. 14	. 001117	. 064	21. 4
	6. Tangential, outside	....	....	88, 800	37, 000	0. 1717	. 001200	. 064	21. 4
	7. Radial, top	....	....	81, 400	35, 000	0. 04	. 001033	. 014	5. 0
	8. Radial, top	....	....	84, 040	39, 000	0. 05	. 001183	. 024	8. 4
	9. Radial, bottom	....	....	87, 720	36, 000	0. 1117	. 001183	. 054	18. 3
	10. Radial bottom	....	....	88, 800	37, 000	0. 1283	. 001283	. 064	21. 4
Top.	11. Longitudinal, outside	....	....	78, 480	40, 000	0. 035	. 001350	. 024	8. 4
	12. Longitudinal, middle	....	....	86, 000	43, 000	0. 035	. 001367	. 014	5. 0
	13. Longitudinal, inside	....	....	84, 000	47, 000	0. 035	. 001550	. 024	8. 4
Bottom.	14. Longitudinal, inside	....	....	80, 480	37, 500	0. 18	. 001200	. 094	30. 6
	15. Longitudinal, middle	....	....	81, 800	38, 000	0. 0983	. 001233	. 054	18. 3
	16. Longitudinal, outside	....	....	79, 840	36, 000	0. 0683	. 001133	. 034	11. 2
	17. Radial, middle	7. 8519	17. 35	63, 680	39, 000	0. 0217	. 001383	. 004	1. 5
	18. Radial, middle	....	....	79, 200	36, 000	0. 0517	. 001150	.....	....

COMPRESSION TESTS.

	Ultimate strength per square inch of original section.	Elastic limit per square inch.	Compression per inch at elastic section.
	Pounds.	*Pounds.*	*Inch.*
19. Radial, middle	67, 400	39, 000	0. 001283
20. Radial, middle	65, 980	39, 000	0. 001350
21. Longitudinal, inside	74, 800	45, 000	0. 001517
22. Longitudinal, outside	65, 700	41, 350	0. 001400

TRANSVERSE TESTS.

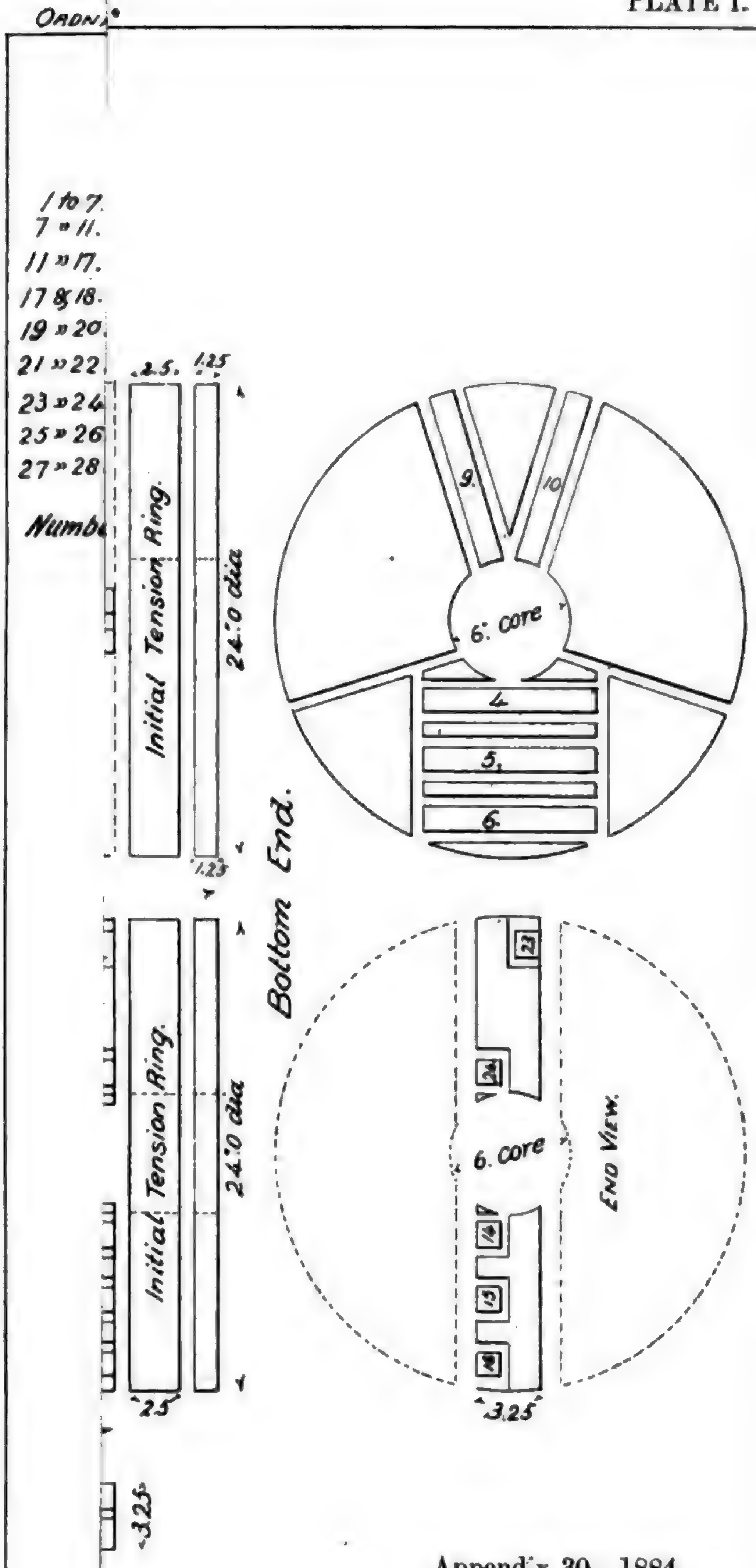
		Maximum fiber strain.	Elastic limit.	Ultimate deflection.	Deflection at elastic limit.
		Pounds.	*Pounds.*	*Inches.*	*Inch.*
Bottom.	23. Longitudinal, outside	136, 680	54, 000	4. 0	. 1038
	24. Longitudinal, inside	132, 000	56, 000	5. 06	. 1093

TANGENTIAL TESTS.

		Bursting strength per square inch.	Elongation of exterior diameter.
		Pounds.	*Inch.*
Middle.	25. Radial, outside	86, 512	. 0435
	26. Radial, inside	72, 744	....
	27. Longitudinal, outside	72, 093	....
	28. Longitudinal, inside	74, 884	. 0425

Initial tension, 16,000 pounds per square inch.

PLATE I.



Appendix 30—1884.

APPENDIX 31.

REPORT ON PHYSICAL PROPERTIES OF MATERIALS FOR GUN CONSTRUCTION BY THE SOUTH BOSTON IRON WORKS.

BY CAPT. D. A. LYLE, ORDNANCE DEPARTMENT.

All tests of an elaborate nature were made at Watertown Arsenal upon specimens taken from the castings made at this foundry.

The tests for tenacity and density made here have been tabulated below under their appropriate headings.

TABLE 1.—Sabots (Butler) for 250 4.2-inch projectiles; composition, 75 per cent. copper, 25 per cent. zinc.

No tests made except taking weights of the finished sabot to see that they came within proper limits.

TABLE 2.—*Density and tenacity of metal, and weight of 8-inch Eureka cored shot made at the South Boston Foundry, under contract dated June 23, 1883.*

Date.	Number cast.	Tenacity.	Density.	Remarks.
Sept. 5	15	27, 410	7. 2085	178 = 2
Sept. 19	2	....	....	179 = 45
Sept. 26	20	25, 596	7. 1801	180 = 154
Oct. 9	16	27, 015	7. 1745	181 = 190
Oct. 11	29	32, 790	7. 2541	182 = 97
Oct. 13	39	31, 124	7. 2546	183 = 12
Oct. 15	29	26, 074	7. 1860	
Oct. 17	30	25, 727	7. 2007	Total . . 500
Oct. 18	33	35, 367	7. 2811	Mean . . 180.7 pounds.
Oct. 19	34	38, 703	7. 1997	
Oct. 20	30	24, 882	7. 1968	
Oct. 22	34	28, 710	7. 1671	
Oct. 23	31	28, 436	7. 2012	
Oct. 24	30	28, 579	7. 1757	
Oct. 25	31	30, 214	7. 1822	
Oct. 26	30	34, 098	7. 2480	
Oct. 27	33	28, 977	7. 0086	
Oct. 29	31	32, 715	7. 2517	
Oct. 30	31	27, 594	7. 1889	
Oct. 31	32	26. 836	7. 2231	

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity (actual).	Hardness (unit of measure = .1 inch).
Maximum	7. 2811	35, 367	15. 05
Minimum	7. 0086	24, 882	9. 31
Mean...........	7. 1982	29, 126	12. 92

TABLE 3.—Fifty 8-inch muzzle-loading rifles, converted, breech insertion.

The tests for the tubes and muzzle collars were made at Cold Spring, N. Y.

The only test made at this foundry upon this contract was on specimens taken from breech before piercing of gun, South Boston Foundry, No. 2305, used to replace a 10-inch Rodman smooth-bore gun spoiled in boring.

The original record for this gun made at time of casting was: Density, 7.2310; tenacity, 32,204. The test specimens from breech taken in 1884 gave: Density, 7.2663; tenacity, 36,959.

TABLE 4.—*Trial cylinder for castings of mortar and guns, made under contract of September 24, 1883.*

Four trial cylinders were cast between December 2 and December 29, 1883. Their composition was as follows :]

Iron.			Density.	Tenacity.
First cylinder (rejected)	½ Lanesboro ¼ Shaparoon ¼ Richmond		7. 31	36, 000
Second cylinder (rejected)	⅓ Muirkirk ⅓ Dover ⅓ Shaparoon		7. 33	33, 866
Fourth cylinder (rejected)	½ Richmond ¼ Lanesboro ¼ Shaparoon	No. 1	7. 2763	29, 176
		No. 2	7. 2742	25, 642
		No. 3	7. 2822	29, 444
		No. 4	7. 2827	29, 621
Third cylinder	½ Richmond, remelted ¼ No. 2 Lanesboro ¼ No. 3 Richmond	No. 1	7. 3191	*32, 095
		No. 2	7. 2982	*33, 631
		"XVII"	7. 3277	†29, 975
		"XVIII"	7. 3013	‡32, 220

*Fracture coarse. †Inside. ‡Outside.

The third cylinder, being deemed the best, was cut up and specimens sent to Watertown Arsenal for testing.

TABLE 5.—12-*inch muzzle loading rifle mortar, hooped with steel.*

[Test specimens taken from initial tension ring cut from muzzle.]

TANGENTIAL SPECIMENS.

Specimen.	Density.	Tenacity.
No. 1	7. 2660	29, 493
No. 2	7. 2740	30, 328
No. 3	7. 2514	31, 753
No. 9	7. 2550	30, 695
No. 10	7. 2615	31, 669
No. 11	7. 2754	31, 991

LONGITUDINAL SPECIMENS.

Outside...	7.2155	25,023
Inside....	7.2595	27,764
No. 12....	7.2382	31,506
No. 13....	7.2685	31,212
No. 14....	7.2622	32,715
No. 15....	7.2600	29,188
No. 16....	7.2471	29,974
No. 17....	7.2495	30,328

Diameter initial tension cylinder	inches..	32.375
Width of slot before rupture	do....	.511
Width of slot after rupture	do....	.612
Total extension on exterior	do....	.101
Extension per linear inch of exterior circumference	do....	.000993
Initial tension	pounds..	15,750

TABLE 6.—*12-inch muzzle-loading rifle mortar, hooped with steel.*

[Test specimens taken from initial tension ring, cut from experimental hooping cylinder after the hoops were removed.]

TANGENTIAL.

Specimen.	Density.	Tenacity.
No. 9....	7.2578	*28,037
No. 10....	7.2721	†31,102
No. 11....	7.2709	‡30,569

*Outside. †Middle. ‡Inside.

INITIAL TENSION.

Mean diameter initial tension ring	inches..	31.0461
Width of slot before rupture	do....	0.5
Width of slot after rupture	do....	0.571
Difference	do....	0.071
Extension per linear inch of exterior circumference	do....	0.0007279
Initial tension	pounds..	12,0 0

TABLE 7.—*10-inch breech-loading rifle, wire-wrapped.*

[Test specimens taken from initial tension ring cut from muzzle.]

TANGENTIAL.

Specimen.	Density.	Tenacity.
No. 1......	7.2942	32,947
No. 2......	7.2849	30,163
No. 3......	7.2819	30,026

LONGITUDINAL.

No. 12....	7.2805	32,716
No. 13....	7.2776	31,831
No. 14....	7.2717	32,273

INITIAL TENSION.

Width of slot after rupture	inches	.604
Width of slot before rupture	do	.503
Difference	do	.101
Mean of three diameters of ring	do	34.125
Extension per linear inch of exterior circumference	do	.00094
Initial tension	pounds	16,100

TABLE 8.—*10-inch breech-loading rifle, wire-wrapped.*

[Test specimens taken from initial tension ring cut from breech.]

TANGENTIAL.

Specimen.	Density.	Tenacity.
No. 1	7.2889	34,749
No. 2	7.2811	32,361
No. 3	7.2804	32,715

LONGITUDINAL.

Specimen.	Density.	Tenacity.
No. 12	7.2787	31,301
No. 13	7.2854	32,770
No. 14	7.2726	33,268
No. 15	7.2875	32,701
No. 16	7.2710	34,301
No. 17	7.2703	31,791

INITIAL TENSION.

Mean diameter initial tension cylinder	inches	31,026
Width of slot before rupture	do	.506
Width of slot after rupture	do	.567
Difference	do	.061
Extension per linear inch of exterior circumference	do	.00061
Initial tension	pounds	13,125

TABLE 9.—*12-inch breech-loading cast-iron rifle, cast breech up.*

[Test specimens taken from initial tension ring cut from the breech.]

TANGENTIAL.

Specimen.	Density.	Tenacity.
No. 1	7.3298	35,508
No. 2	7.2867	29,099
No. 3	7.3725	38,438

LONGITUDINAL.

Specimen.	Density.	Tenacity.
No. 12	7.3445	33,455
No. 13	7.2718	30,947
No. 14	7.3771	38,236

RADIAL.

No. 20....	7. 2875	33, 213
No. 21.....	7. 3223	34, 541
No. 22.....	7. 3574	34, 630

INITIAL TENSION.

Exterior diameter of ring	inches..	57. 15
Width of slot before rupture	do....	. 5
Width of slot after rupture	do....	. 6615
Total extension on exterior	do....	. 1615
Extension per linear inch on exterior	do....	. 000899511
Initial tension	pounds..	15, 750

The other specimens from the breech ring will be sent to Watertown Arsenal for tests.

Twelve-inch breech-loading cast-iron rifle, cast breech up, muzzle ring. This has not been taken from the gun yet.

TABLE 10.—*Densities and tenacities of 3-inch shot.*

Date.	Number cast.	Tenacity.	Density.	Date.	Number cast.	Tenacity.	Density.
Nov. 21	10	....	....	Dec. 1	18	29, 493	7. 2419
Nov. 23	34	29, 325	7. 2338	Dec. 3	20	28, 514	7. 2295
Nov. 24	12	25, 907	7. 2206	Dec. 4	20	31, 212	7. 2124
Nov. 26	30	31, 176	7. 1905	Dec. 5	20	23, 254	7. 1813
Nov. 27	20	31, 085	7. 2020	Dec. 6	20	23, 111	7. 1711
Nov. 28	20	31, 389	7. 2128	Dec. 7	20	29, 178	7. 2308
Nov. 30	20	24, 934	7. 1608				

TABLE 11.—*Densities and tenacities of 3-inch shell.*

Date.	Number cast.	Tenacity.	Density.	Date.	Number cast.	Tenacity.	Density.
Nov. 23	32	....	....	Dec. 3	19	29, 797	7. 2093
Nov. 24	18	28, 247	7. 2178	Dec. 4	20	27, 013	7. 2002
Nov. 26	26	28, 294	7. 1894	Dec. 5	20	28, 784	7. 1969
Nov. 27	20	27, 404	7. 1911	Dec. 6	20	29, 936	7. 1641
Nov. 28	20	30, 648	7. 2083	Dec. 7	20	27, 311	7. 2015
Nov. 30	24	23, 166	7. 1547	Dec. 29	36	24, 445	7. 1833
Dec. 1	20	25, 292	7. 1839				

TABLE 12.—*Densities and tenacities of 4.5-inch shot.*

Date.	Number cast.	Tenacity.	Density.	Date	Number cast.	Tenacity.	Density.
Dec. 17	24	29, 355	7. 2308	1884.			
Dec. 18	42	27, 810	7. 2257	Jan. 5	14	24, 887	7. 2226
Dec. 21	42	28, 560	7. 2148	Jan. 7	48	27, 587	7. 2042
Dec. 22	17	28, 206	7. 1948	Jan. 8	16	23, 514	7. 1803
Dec. 27	47	25, 023	7. 1914	Jan. 10	48	25, 783	7. 1741
Dec. 29	9	29, 869	7. 2316	Jan. 11	10	24, 757	7. 1249

TABLE 13.—*Densities and tenacities of 4.5-inch shell.*

Date.	Number cast.	Tenacity.	Density.	Date.	Number cast.	Tenacity.	Density.
Nov. 23	29	25, 041	7. 2179	Dec. 6	17	32, 627	7. 2228
Nov. 26	10	28, 729	7. 2678	Dec. 7	17	26, 055	7. 1672
Nov. 27	31	30, 454	7. 2036	Dec. 10	23	23, 562	7. 1949
Nov. 28	19	30, 239	7. 2000	Dec. 29	17	23, 431	7. 1930
Nov. 30	20	31, 919	7. 2286	1884.			
Dec. 1	20	30, 062	7. 2321	Jan. 1	32	22, 478	7. 1923
Dec. 3	20	28, 518	7. 1620	Jan. 3	32	23, 824	7. 1865
Dec. 4	15	30, 947	7. 2138	Jan. 5	20	24, 887	7. 2226
Dec. 5	17	27, 410	7. 1721	Jan. 11	20	24, 757	7. 1249

TABLE 14.—Fifty Butler sabots for 8-inch projectiles. Composition: Copper, 75 per cent.; zinc, 25 per cent. No tests made of this metal.

TABLE 15.—Five hundred 15-inch solid shot for 15-inch Rodman smooth-bore guns.

The castings for these shot were made from iron melted in the "Hayden vapor fuel furnace." The details will be given in a report (now in progress) upon that furnace.

In order to indicate the quality of the castings made by this process the following grand mean results are given, viz: Density, 7.3044; tenacity, 32,856 pounds per square inch.

APPENDIX 32.

CONSTRUCTION REPORT OF 3 AND 4½ INCH PROJECTILES WITH BUTLER SABOT FOR MUZZLE-LOADING RIFLES, MADE AT THE WEST POINT FOUNDRY NOVEMBER, 1883, TO FEBRUARY, 1884.

BY LIEUT. ROGERS BIRNIE, JR., ORDNANCE DEPARTMENT.

(3 plates.)

During the manufacture of these projectiles an opportunity was afforded for observing defects in the methods used in casting the 3-inch shot and shell. In the case of the shot an improvement was made, but with these, and especially with the 3-inch shell, a different method, as the founders themselves recognize, should be adopted. This will consist principally in more careful preparations for casting and the use of iron core-boxes instead of wooden ones. To illustrate this matter, I submit a somewhat detailed description of the methods used in casting, which, in connection with the inspection reports herewith, will forcibly show the advantage, to the manufacturer as well as the Government, of careful preparations for casting. The following projectiles were ordered: 250 3-inch cored shot, weight, 10½ pounds; 250 3-inch shell, weight, 8¼ pounds; 300 4½-inch cored shot, weight, 34¾ pounds; 250 4½-inch shell, weight, 31¼ pounds.

The 4½-inch to be made of iron having a tenacity of not less than 23,000 and the 3-inch of not less than 18,000 pounds per square inch.

The 4½ inch shot was designed to be cast with a core, as given above, but two shot cast in this way at the South Boston Iron Works, preparatory to making the same projectiles under a duplicate order, gave a weight of 31¼ and 31½ pounds, respectively. Following this, the West Point Foundry was requested to cast a few sample 4½-inch *solid* shot, retaining the exterior dimensions of the cored shot; the result gave a shot weighing 36 pounds, with iron of density equal to 7.2602 and tenacity of 27,000 pounds per square inch. Assuming this as about the maximum density that would be obtained in the manufacture, one of these sample shot was reduced by turning off the base in order to bring it within the limit of + 1½ per cent. of the standard weight of 34¾ pounds. Upon reporting the results of this investigation, the Chief of Ordnance fixed the standard weight of the shot at 35 pounds, and directed that it be cast solid with dimensions shown in Plate I. The dimensions of the remaining projectiles as manufactured are given in the same plate.

The patterns and molds prepared for casting the 4½-inch projectiles are shown in Plate II, and those for the 3-inch in Plate III.

4½-INCH SHELL CASTINGS.

Careful preparations were made for these, including an iron core-box, Fig. 1, Plate II, in which a hollow core-stem is carefully adjusted by means of the cone and exterior nut at its upper end. The cross-bar in the flask, Fig. 5, is arranged to receive this cone with the same adjustment after the core has been made. Besides this, the shell pattern, Fig. 2, has an iron stem projecting from the wood which likewise fits in the cross-bar of the flask, and in this way the exact dimensions of the mold, when finally arranged for casting in the flask, are assured. Fig. 3 represents a plan of the wooden molds used for making the sand stem of the core, the space within the iron flask being too confined for tamping this portion of the core. In using these molds, the iron stem after being wrapped is laid in the lower half, the sand is then filled in and rounded about it and afterwards compressed and shaped by placing the upper half of the mold. The core-stem is made of a piece of iron gas-pipe 0.4 inch exterior diameter, the smallest size made being used for these projectiles.* This stem is perforated in a number of places and wrapped with hemp to allow free escape of the gas developed during the casting, and thus prevents the core from bursting. These projectiles were cast two in each flask with the point down, as shown in Fig. 5, Plate II, and a riser was provided from the base of each. It was not found necessary to feed the casting through the riser as in the case of larger projectiles. The pattern, Fig. 2, following the usual practice for all projectiles, was made about 0.2 inch larger than the finished size over the cylindrical portion, to allow for finishing. This surface is joined to the head by a shoulder, which is entirely removed in the finishing, and permits, as has been found by experience, a better finish than if the curve of the head were distorted and joined to the surplusage of the body as a tangent. In the direction of the length the only surplus allowed for finishing was about one-sixteenth of an inch at the rear and one-eighth of an inch at the front of the cylindrical portion.

It may be remarked here that the usual method is to cast shell with the base down to insure strength in that portion. But with projectiles of this size it is not deemed a matter of importance. Moreover, in that case "feeding" is generally resorted to, and with the "riser" coming from one side of the head the lightness of the stem in these projectiles would endanger the disarrangement of the core under this process with the continued feeding of hot iron so near it.

The following gives the record of castings for these projectiles, including the average weight of projectile in the rough and the tenacity and density of the metal. All the castings were made directly from the air-furnace:

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*It would be better in this case to use the next larger size of gas-pipe—½ inch exterior diameter—as it would be much more durable; the smallest size above should be used only for projectiles of about 3-inch caliber.

The suitable size of stem (gas-pipe) for a core depends primarily upon the caliber of the projectile. For an 8-inch projectile not less than a five-eighths inch (exterior diameter) pipe should be used, and for a 10-inch a seven-eighths inch (exterior diameter.) From this we arrive at the practical minimum diameter that should be fixed for the fuse or screw plug-hole of the several calibers, since the hemp and sand placed around the stem may have at the least a thickness of one-eighths inch, but better three-sixteenths inch, or even more. We have, then, the following minimum diameters of sand stem, or what is the same thing, of fuse or screw-plug hole in the *rough:* For all 3-inch projectiles, or 4½-inch *shot*, 0.525 inch; for 4½-inch shell and intermediate calibers to include an 8-inch *shot*, 0.875 inch; for an 8-inch shell and larger calibers of projectiles, 1.25 inches; and allowing at the least one-sixteenth of an inch on a side for finishing, we find that the minimum *clearance* for the fuse or screw-plug hole, to allow a safe casting of the several classes named, should be, respectively, 0.75, 1.0, and 1.375 inches. Otherwise, one of two expedients must be adopted—either to cast the projectile with a core stem too light for the work it has to do and thus entail loss, or to cast with a suitable stem and afterwards reduce the diameter of the finished hole by means of a thimble. This latter expedient is resorted to where the diameter of the *standard* fuse is within the minimum clearance given above.

Record of castings—4½-inch shell.

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.			Tenacity.	Density.	Remarks.
			Shaparoon No. 2.	Hudson No. 2.	Air-furnace scrap.			
1883.								
Dec. 12	24	31. 5	......	69. 0	30. 9	25, 312	7. 2187	Specimens taken from 4½-inch solid shot of same castings.
Dec. 27	52	31. 2		66. 6	33. 8	24, 725	7. 1724	
Dec. 31	74	31. 4	12. 9	61. 5	25. 5	28, 675	7. 2318	
1884.								
Jan. 3	74	31. 4	13. 0	62. 0	25. 0	22, 492	7. 2038	Specimens taken from 3-inch round bar of same castings.
Jan. 5	50	31. 4	13. 0	62. 0	25. 0	25, 949	7. 2038	

4½-INCH SHOT CASTINGS.

In making this projectile solid the casting became a simple matter. The pattern, Fig. 4, Plate II, was made with the usual surplus about the body and short cylinder at the point to insure a good finish. In Fig. 5, the mold is arranged for casting with the base up; some of these shot, however, were cast with the point up, to the detriment of their quality. With this latter mode of casting, some of the points lacked solidity when finished—certainly an undesirable quality in a shot. The following gives the record of castings for these projectiles. Two of the lots were cast at the same time with the shell given above. These projectiles were also cast directly from the air-furnace:

Record of castings—4½-inch solid shot.

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.				Tenacity.	Density.	Remarks.
			Shaparoon No. 2.	Hudson No. 2.	Air-furnace scrap.	Shot.			
1883.									
Dec. 8	4	37. 0	5. 6	48. 3	46. 0	......	27, 019	7. 2602	All specimens taken from shot, one of each lot being cut up for the purpose.
Dec. 12	58	35. 5	......	69. 0	30. 9	......	25, 812	7. 2187	
Dec. 15	84	35. 0	......	66. 6	33. 8	......	29, 041	7. 2120	
Dec. 20	80	35. 3	......	50. 0	50. 0	......	26, 928	7. 2283	
Dec. 22	80	35. 6	......	48. 4	.....	51. 5	27, 692	7. 2655	
Dec. 27	36	35. 7	......	66. 6	33. 3	......	24, 725	7. 1724	

3-INCH SHELL CASTINGS.

The method at present in vogue at this foundry involves the use of wooden core-boxes for casting projectiles of this caliber. Fig. 1, Plate III, shows the plan and elevation of one-half the core mold for shell. The stem consists of a straight piece of iron, 0.375 by 0.1 inch in cross-section, turned at the point (not shown in the drawing) to hold the sand, and having an eye at the base for adjustment of the core in the flask. In making the core the halves of the box are filled separately with the stem half imbedded; a wire is laid under the stem in each half to give a double vent throughout the length of the core. After the halves have been made they are stuck together with clay wash. The sand stem is made conical for the same purpose as in the case of the iron box. The pattern, Fig. 2, is also made entirely of wood, and has a stem at the point to prepare a print in the flask for the reception of the sand stem of the core. The iron stem is not wrapped with hemp. These projectiles were all cast base up, and arranged two in a flask with two shot of the same caliber, as shown in Fig. 5, Plate III. A single riser was arranged for the two shells, and opened from the junction of the upper and lower portions of the flask instead of from the base of the projectile. The pattern, Fig. 2, was made with relatively the same surplus for finishing as in the case of the 4½-inch shell. The following gives the record of castings:

Record of castings.—3-inch shell.

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.									Proportion of cupola iron used.	Tenacity.	Density.
			Air-furnace.				Cupola.							
			Shaparoon No. 2.	Hudson No. 2.	Air-furnace scrap.	Shot.	Hudson No. 1.	Hudson No. 2.	Poughkeepsie.	Scotch.	Foundry scrap.			
1883.														
Nov. 24	50	8.0	13.0	42.0	36.0	12.0	......	50.0	......	......	50.0	½	24,733	7.2351
Dec. 3	33	9.0	5.6	48.3	46.0	......	......	41.6	41.6	......	16.6	½	28,108	7.2069
Dec. 6	50	8.83	6.0	47.0	47.0	......	......	46.0	30.0	......	24.0	½	25,011	7.1897
Dec. 12	50	9.0	......	69.0	30.9	......	49.2	29.1	21.5	......	......	½	......	......
Dec. 15	50	8.8	......	66.6	33.3	......	......	50.0	30.0	......	20.0	½	......	......
Dec. 27	50	8.8	......	66.6	33.3	......	28.7	28.7	......	19.1	23.5	½	......	......
Dec. 31	50	8.9	12.9	61.5	25.5	......	12.5	30.3	......	3.3	54.1	⅓	22,402	7.2140
1884.														
Jan. 24	50	8.8	24.0	57.7	18.3	......	40.3		....	9.2	50.4	5/13	24,870	7.1875
Jan. 29	18	9.0	......	57.4	42.5	......	......	50.0	....	......	50.0	½	25,895	7.2442

NOTE.—Specimens taken in each case from round bar of same casting.

3-INCH SHOT CASTINGS.

Figs. 3, 4, and 5, Plate III, show the final arrangements adopted for casting these projectiles. The changes, which were made after a number had been cast, consisted in: (1) Increasing the diameter of the sand stem of the core; (2) making the length of base about three-eighths of an inch surplus; and (3) carrying a separate riser from the base of each shot. At first the sand stem of the core was made but 0.5 inch diameter, and the iron stem within was but 0.25 by 0.0625 inch in cross-section. Afterwards the sand stem was enlarged to 0.625 inch diameter, and the same iron was introduced as in the shell. At first also the pattern was made to cast a finished base (at rear), and one riser was fixed for the two shot as for the shell. Under the first arrangements many of the shot were eccentric because the core-stem was too light, and many others were defective at the base. The latter defect was entirely remedied by providing an increased length of base to be turned off and having a riser from the base; the change in the riser alone would probably have effected the improvement at the base. In fixing the core of the shot in position in the flask, the sand stem was fastened into the print made by the pattern by a paste of clay wash.

The following gives the record of the castings:

Record of castings.—3-inch shot.

Date.	Number cast.	Average weight in rough state.	Charge of iron in percentages.									Proportion of cupola iron used.	Tenacity.	Density.
			Air-furnace.				Cupola.							
			Shaparoon No. 2	Hudson No. 2	Air-furnace scrap.	Shot.	Hudson No. 1.	Hudson No. 2	Poughkeepsie.	Scotch.	Foundry scrap.			
1883.														
Nov. 24	50	10.2	13.0	42.0	36.0	12.0	......	50.0	.....	......	50.0	½	24,733	7.2351
Dec. 3	34	10.46	5.6	48.3	46.0	......	......	41.6	41.6	......	16.6	[illegible]	28,108	7.2069
Dec. 6	50	11.3	6.0	47.0	47.[illegible]	....	...	46.0	30.0	......	24.0	[illegible]	25,011	7.1897
Dec. 12	50	11.3	.....	69.0	30.9	......	40.2	29.1	21.5	......	......	[illegible]	....	....
Dec. 15	50	11.3	......	66.6	33.3	......	.	50.0	30.0	......	20.0	[illegible]	....	....
Dec. 27	50	11.1	......	66.6	33.3	......	28.7	28.7	......	19.1	23.5	[illegible]	....	....
Dec. 31	50	11.4	12.9	61.5	25.5	......	12.5	30.3	.....	3.3	54.1	[illegible]	22,402	7.2140
1884.														
Jan. 5	52	11.4	13.0	62.0	25.0	.....	21.1	9.0	......	18.2	51.1	[illegible]	22,454	7.2034
Jan. 24	50	10.5	24.0	57.7	18.3	......	40.8	......	.....	9.2	50.4	5/13	24,870	7.1875
Jan. 29	61	11.4	......	57.4	42.5	....	.....	50.0	......	.....	50.0	½	25,895	7.2442

NOTE.—Specimens taken in each case from round bar of same casting.

The 3-inch projectiles were all cast from a mixture, varying from one-third to one-half of cupola iron and the remainder of air furnace iron—the two being mixed in a molten state. This mixture gave in each case more than the required tenacity of 18,000 pounds per square inch. But it is believed that many of the defective 3-inch castings arose from the high nature of the iron used, it being apparent that for a casting of this size a smooth and soft iron of barely more than the requisite tenacity would in general be best. As, however, the ordinary run of cupola iron used for current work could not be depended upon to give a tenacity of 18,000 pounds, it became necessary to use the mixture which was softened by the addition of the cupola iron. Another defect arose from this mixture in that the iron sometimes lacked the requisite cleanness. A large proportion of the 3-inch shell were eccentric, and there were also many defective castings.

In connection with what has been said, a comparison of the percentage of losses in the 4½-inch shell cast with the use of an iron core-box with the losses for the 3 inch projectiles will make it apparent that the same preparations should be made for casting the latter as the former, including an iron core-box and flask adapted to it, with a riser also from the base of each projectile; and, preferably, cupola iron from a selected charge should be used.

The records of the final inspection of the several lots of these projectiles follow herewith.

NOTE.—In justice to the manufacturers it must be stated that their orders for 3-inch projectiles, within late years, have been so limited that there has been little or no inducement for them to incur the expense incident to changing their old-established methods of casting to conform to the more exact requirements of the present day.

PACKING BOXES.

The following statement shows the dimensions, &c., of the boxes used, and the number of projectiles packed in each:

Projectiles.		Packing boxes.				Gross weight of package.	Marks on end of box.
Kind.	No.	Interior dimensions.			Weight of box empty.		
		Length.	Width.	Depth.			
		Inches.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	
4½-inch shell	5	22.3	12.25	4.5	18.	173.	W. P. F., 5 4½-inch Butler shell.
4½-inch shot	5	22.3	11.1	4.5	17.	202.	W. P. F., 5 4½-inch Butler shot.
3-inch shell	12	17.9	7.5	7.0	16.5	112.5	W. P. F., 12 3-inch Butler shell.
3-inch shot	12	17.9	7.5	7.0	16.5	142.5	W. P. F., 12 3-inch Butler shot.

The boxes are made of inch pine boards, fastened with nails, and bound at the ends with hoop iron; the size is adapted to the projectiles, so that no packing material was necessary. The 4½-inch projectiles are laid in a single tier with the ends reversed, to protect the sabots and equalize the weight; with the shot, straight pieces about 1 inch square, and equal in length to the depth of the box, were set on either side of each point. The 3-inch projectiles are similarly packed, with the ends reversed across the box, but in two tiers, with a false bottom laid between.

Inspection report of 4½-inch ogival-headed Butler shell for muzzle-loading rifles, made for the United States Ordnance Department by the West Point Foundry Association, at the West Point Foundry, under contract of the Chief of Ordnance, U. S. Army, dated November 13, 1863.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.		
Length of cylindrical portion of body .... inches..	7.5	+0.15
Length of head ....do....	4.35	−0.097
Length of base for sabot ....do....	1.1	±0.05
Total length of projectile ....do....	12.25	±0.1225
Diameter of cylindrical portion ....do....	4.46	±0.01
Diameter of base at bottom of threads ....do...	3.06	±0.01
Radius of head ....do....	6.75	±0.05
Thickness of bottom ....do....	1.25	±0.1
Length of interior cavity ....do....	10.0	±0.1
Thickness of walls at 2.3 inches from base ....do....	0.88	....
Thickness of walls at 7.35 inches from base ....do..	0.88	....
Eccentricity of axis of interior cavity ....do..	....	0.0675
Diameter of fuze hole at bottom of threads ....do...	1.04	±0.01
Pitch of thread on fuze (or screw-plug) hole	12 to the inch.	
Length of thread on fuze (or screw-plug) hole....inch..	1	....
Weight of projectile without sabot ....pounds..	29.05	....
SABOT.		
Height of sabot ....inches..	1.1	±0.01
Exterior diameter of sabot ....do....	4.46	
Interior diameter of sabot ....do....	3.06	
Maximum thickness of outer lip ....do....	0.25	
Minimum thickness of outer lip ....do....	0.15	
Depth of cannelure ....do....	0.6	
Maximum width ....do....	0.2	
Weight of sabot ....pounds..	2.2	
Weight of sabot and projectile ....do....	31.25	±0.47

Number of 4½-inch Butler shell examined.	269
Number rejected for eccentricity of interior cavity	8
Number rejected for defects in material or finish	11
Total number rejected	19
Total number accepted	250
Weight of heaviest one accepted (including sabot)	31.25
Weight of lightest one accepted (including sabot)	30.75

Weight of total number accepted (excluding sabots)	7,175¼
Mean weight of projectile (excluding sabot)	28.701
Number of sabots examined	250
Number of sabots accepted	250
Weight of total number accepted	550
Mean weight of sabot	2.2
Weight of total number of shot and sabots accepted	250

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Mean of 5 specimens	From 7. 1724 To 7. 2318	23, 000	From 22, 492 To 28, 675	—690	From — 502 To +5, 675	75 parts copper. 25 parts zinc.
Average	7. 2061	....	25, 430	... .	+2, 430	

REMARKS.—Made after drawing attached to contract. Shipped February 11, 1884, to New York Arsenal, Governor's Island, New York.

I certify that I have carefully inspected the above-noted projectiles and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

Date of inspection, January 30, 1884.

Inspection report of 4½-inch ogival-headed Butler solid shot for muzzle-loading rifles, made for the United States Ordnance Department by the West Point Foundry Association, at the West Point Foundry, under contract of the Chief of Ordnance, U. S. Army, dated November 13, 1883.

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.		
Length of cylindrcial portion of body ....inches..	5. 77	+0. 115
Length of head ....do....	5. 02	−0. 1
Length of base for sabot.................. ......do...	1. 1	± 0. 05
Total length of projectile.............. ... .do....	11. 1	± 0. 11
Diameter of cylindrical portion ....do....	4. 46	±0. 01
Diameter of base at bottom of threads............do....	3 06	±0. 01
Radius of head ....do...	6. 75	±0. 05
Thickness of bottom................................do ..	1. 525	±0. 1
Weight of projectile..........................pounds	32. 8	....
SABOT.		
Height of sabot ... .inches..	1. 1	±0. 01
Exterior diameter of sabot................ ... do....	4. 46	±0. 01
Interior diameter of sabot.......... .... do...	3. 06	±0. 01
Maximum thickness of outer lip....................do....	0. 25	±0. 01
Minimum thickness of outer lip................ do ...	0. 15	±0. 01
Depth of cannelure...............................do	0. 6	±0. 01
Maximum width ... .do....	0. 2	±0. 01
Weight of sabot.......... ....pounds..	2. 2	....
Weight of sabot and projectile ....do....	35. 0	0. 525

Number of 4½-inch solid shot examined...	305
Number rejected for defects in material or finish	5
Total number rejected	5
Total number accepted	300
Weight of heaviest one accepted (including sabot)..........	35. 25
Weight of lightest one accepted (including sabot)..............................	34. 75
Weight of total number accepted (excluding sabots)..............................	9, 837½

Mean weight of projectile (excluding sabot)	32. 79
Number of sabots examined...............	311
Number of sabots rejected for defects in material or finish......	11
Total number of sabots rejected..........	11
Number of sabots accepted	300
Weight of total number accepted	660
Mean weight of sabot	2. 2
Weight of total number of shot and sabots accepted	10, 497½

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Mean of 6 specimens	From 7. 1724 To 7. 2655	23, 000	From 24, 725 To 29, 041	−690	From +1, 725 To +6, 041	75 parts copper. 25 parts zinc.
Average	7. 226	......	26, 786		+3, 786	

Remarks.—Contract drawing modified by letter Chief of Ordnance, dated December 8, 1883; prescribed weight of shot fixed by same at 35 pounds, and ordered to be cast solid. Standard drawing, inspector's file No. 224. Shipped February 11, 1884, to New York Arsenal, Governor's Island, New York.

I certify that I have carefully inspected the above-noted projectiles and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

R. BIRNIE, Jr.,
Lieutenant of Ordnance, Inspector.

Date of inspection, January 12, 1884.

Inspection report of 3-inch ogival-headed Butler shell for muzzle-loading rifles, made for the United States Ordnance Department by the West Point Foundry Association, at the West Point Foundry, under contract of the Chief of Ordnance, U. S. Army, dated November 13, 1883

Subject of measurement.	Prescribed dimensions.	Allowed variations.
PROJECTILE.		
Length of cylindrical portion of body ....inches..	5. 2	+0. 104
Length of head..........................do...	2. 3	−0. 046
Length of base for sabot ....do...	0. 9	±0. 05
Total length of projectile..........................do ..	7. 5	±0. 075
Diameter of cylindrical portion ....do ...	2. 97	±0. 01
Diameter of base at bottom of threads ....do...	1. 97	±0. 01
Radius of head .... do ...	3. 71	±0. 05
Thickness of bottom ....do ...	1. 0	±0. 1
Length of interior cavity...... ....do...	6. 5	±0. 1
Thickness of walls at 2.05 inches from base......do ...	0. 44	....
Thickness of walls at 4.8 inches from base ..... do...	0. 44	...
Eccentricity of axis of interior cavity ......do ..	....	0. 045
Diameter of fuze hole at bottom of threads ......do....	1. 04	±0. 01
Pitch of thread on fuze (or screw-plug) hole......do ...	12 to the inch.	
Length of thread on fuze (or screw-plug) hole....do ...	1. 0	....
Weight of projectile.................. ....pounds .	7. 455	....
SABOT.		
Height of sabot ....inches..	0. 8	....
Exterior diameter of sabot ....do....	2. 97	....
Interior diameter of sabot ....do....	1. 97	....
Maximum thickness of outer lip..................do ...	0. 15	....
Minimum thickness of outer lip ....do....	0. 1	....
Depth of cannelure.......................... ... ..do....	0. 5	....
Maximum width..................................do ..	0. 15	....
Weight of sabot..................................pounds .	0. 795	....
Weight of sabot and projectile.................. do ..	8. 25	0. 124

Number of 3-inch Butler shells examined..	394
Number rejected for erroneous dimensions of head	50
Number rejected for erroneous dimensions of cylindric body or base	3
Number rejected for eccentricity of interior cavity	37
Number rejected for defects in material or finish..................................	54
Total number rejected	144
Total number accepted....	250
Weight of heaviest one accepted (including sabot)..............................	8. 25
Weight of lightest one accepted (including sabot)....	8. 0
Weight of total number accepted (excluding sabots)........	1, 810. 5
Mean weight of projectile (excluding sabot)...	7. 21
Number of sabots examined............	250.
Number of sabots accepted	250.
Weight of total number accepted ...	189. 75
Mean weight of sabot	0. 795
Weight of total number of shot and sabots accepted	2, 000. 25

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity.				Sabot metal.
		Prescribed.	Actual.	Allowed variations.	Actual variations.	
Mean of 6 specimens	From 7.1875 To 7.2442	18,000	From 22,454 To 28,108	−540	From +6,454 To +10,108	75 parts copper. 25 parts zinc.
Average.....	7.2176	....	24,790	....	+6,790	

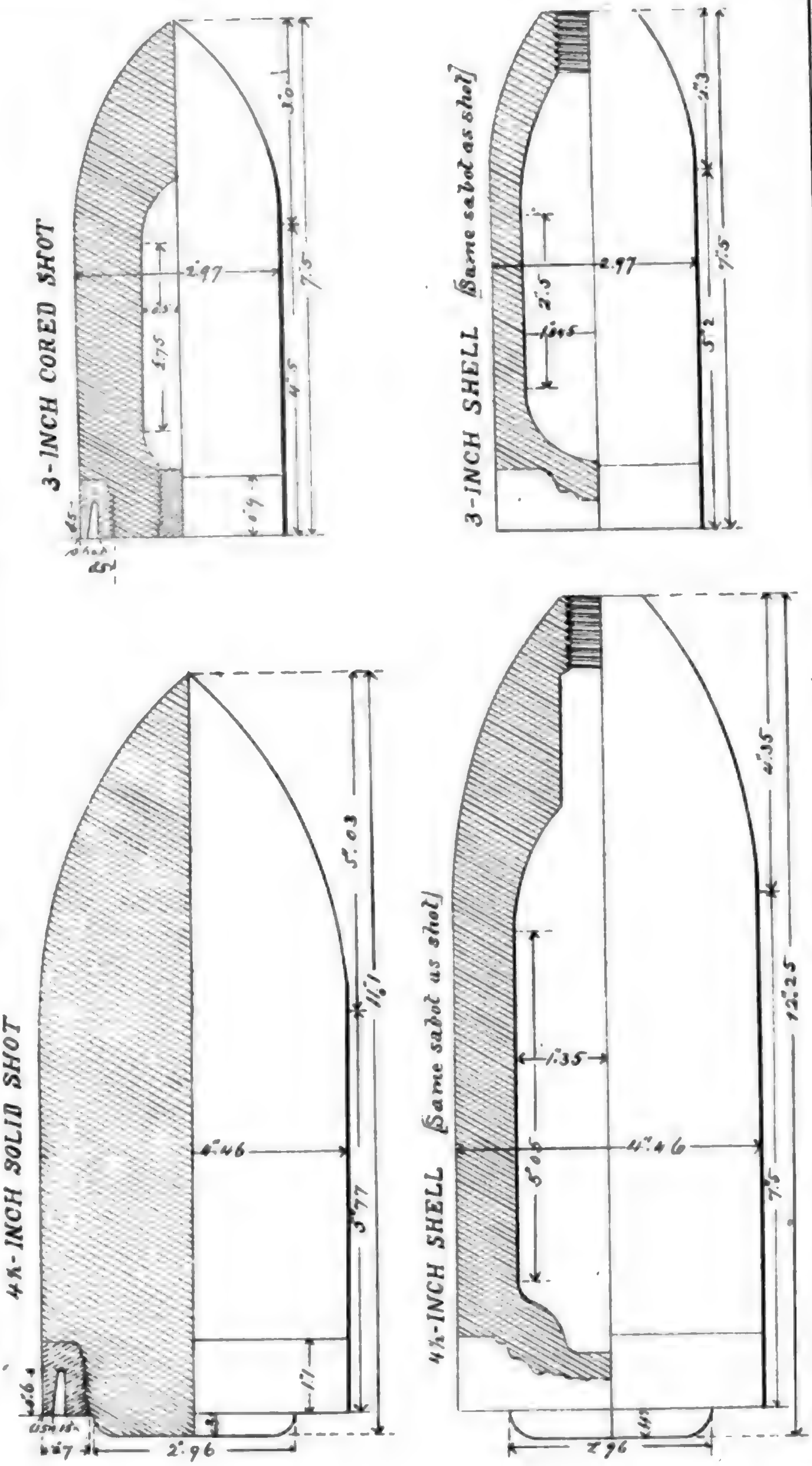
REMARKS: Made after drawing attached to contract. Shipped February 11, 1884, to New York Arsenal, Governor's Island, New York.

I certify that I have carefully inspected the above-noted projectiles and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

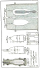
R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

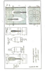
Date of inspection, February 7, 1884.

3 AND 4½-INCH PROJECTILES WITH BUTLER SABOT



Appendix 32—1884.





APPENDIX 32*a*.

MANUFACTURE OF SABOTS FOR MUZZLE-LOADING PROJECTILES.

BY LIEUT. R. BIRNIE, JR., ORDNANCE DEPARTMENT.

(1 plate.)

The following notes relate to the manufacture of the Butler sabot by the method at present in vogue at this foundry.

The composition is an alloy containing 70 parts copper and 30 parts zinc. These metals are carefully selected for purity, the best brands in the markets being purchased. Those at present used are: Lake Superior ingot copper, Quincy Mining Company, and Bergenport spelter, made from pure Lehigh ore. The Lehigh spelter, which some years since held the first place in the market, is said to be no longer manufactured.

In commencing an order, dated May 27, 1884, for 300 of these sabots for 8-inch muzzle-loading projectiles, only new metals, as above, were used, and no brass or composition was afterward introduced in the charges of the furnaces except the "gates" and chips from current castings, together with an occasional imperfect casting. The castings were examined as soon as made, and the imperfect ones laid aside for remelting. The imperfections apparent at this stage consist principally of cavities in the outer surface, but it may happen that the metal in the crucible becomes too cool before its contents are emptied, in which case one or more of the last castings poured from it will be imperfectly filled out. A casting which passes this first inspection is, if the patterns are carefully made to give sufficient metal for the finish, rarely thrown out in the finishing shop or at the final inspection. At this inspection serious defects may be anticipated only under the "gate." There the metal may be drawn and more or less honey-combed under the surface, with perhaps only a small orifice at the exterior; elsewhere probably all the bad features of the metal will be apparent on the surface.

The patterns are made almost entirely of hard wood, but finished and put together with care, not only to secure accuracy in dimension but also to give no more than just sufficient surplus metal for the finish, and thus avoid waste in turning. Drawings of the several parts are appended.

Figs. 1 and 2 represent the two parts of the core-pattern. The object of this pattern is to make a core for rough-casting the cavity in the sabot under the lip; the size and shape of this cavity, combined with the tendency of the metal to clog the cutting tool, makes it advisable to use this method instead of cutting out the cavity from a solid casting, but the core is a difficult and delicate piece to mold and considerably increases the time and labor employed for the casting.

In making the core the two parts of the pattern are put together as shown in Fig. 2. The circular cavity of triangular cross-section, *a a*, is first filled with fine molding-sand, and then inch brads are stuck half way in at short intervals around the middle of the top surface to hold this rim to the body of the core-mold above. Next the mold is filled nearly to the surface, and the two sustaining rings of iron (Fig. 3) are embedded. The mold is then tamped and finished, turned upside down, and the patterns withdrawn. The core is next brushed with a wash of black-lead and finally "dried" for use. The completed core is shown in position in Fig. 5. For some castings the molder used only fine prepared molding-sand for the core; for others he used a mixture of this sand with one-fourth fire-sand, the result being that the fire-sand is not considered a necessary ingredient; the sufficiency of the molding-sand alone will depend, however, upon its manipulation, and especially upon the experience of the molder.

The sabot pattern is shown, Fig. 3. It is built up in sections of hard wood and has a couple of metal plates embedded in the lower surface, in the center of which are threaded holes for the introduction of a key to be used in withdrawing the pattern from the mold. The portion *b b* of this pattern makes a cavity in the mold which receives the body of the core *c c*, of corresponding shape, as shown.

The boxes for the mold (Fig. 5) are of rough wood. For this portion of the mold (all except the core) the sand is used "green." The sides of the several patterns are sloped to constitute a "draw," or, in other words, to facilitate the withdrawal of the patterns in making the molds.

Shrinkage.—It may be observed that both the exterior and interior diameters of the sabot patterns are larger than those of the finished sabot, but it is found that the shrinkage of each of these diameters in the casting is about 0.125 inch, so that the rough castings are of satisfactory dimensions. If, however, the inner diameter remains, after the casting is cool, slightly larger than the 5.75 inches prescribed *within the threads*, it will be found that the cutting of the threads will crowd the metal inward sufficiently to overcome the scantness. As, for instance, sabots which gave an interior measurement of 5.77 inches in the rough casting were found to fit the gauge* accurately when finished.

Casting.—The furnace is an ordinary brass-molder's furnace with double cylinders, each of which holds one crucible.

The capacity of the latter, used for this work, is about 160 pounds, and run from 10 to 12 sabot castings each.

The following is a record of the castings, &c.:

Castings.			Metals used.				Spelter.	Remarks.
Date.	Number cast.	Average rough weight of sabot.	Ingot copper.	Brass (once melted.)	Spelter.	Total weight of metals in charge.		
1884.		*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	
May 29	6	12	80	....	34	114	29.8	About 5 per cent. by weight of the metal wasted in the melting.
May 30	18	12	150	37	64	251	29.9	About 3 per cent. of the metal wasted as above.
May 31	20	12	178	25	76.5	279.5	30.0	
June 2	16	12	170	40	73	283	30.0	
June 5	18	12	182	....	79	261	30.3	
June 6	20	12	161	60	68	289	29.7	
June 7	20	12	194	20	85	299	30.5	
June 9	20	12.4	166	50	72	288	30.2	
June 10	20	12.4	180	35	77	292	30.0	
June 11	20	12.4	177	40	76	293	30.0	
June 12	23	12.4	180	60	77	317	30.0	
June 13	23	12.4	196	50	84	330	30.0	
June 14	23	12.4	175	70	75	320	30.0	
June 16	23	12.4	178	70	78	326	30.5	
June 17	23	12.4	192	50	83.5	325.5	30.3	
June 18	21	12.4	105	150	45	300	30.0	

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* See Report of Chief of Ordnance, U. S. Army, 1880, bottom of page 215.

The percentage of zinc (or spelter) is calculated from the quantity of new metals introduced in the charge. This quantity is made to depend upon the capacity of the crucible and the amount of brass ("gates" and imperfect castings) available at the time; generally, however, the amount of brass used is limited to about 15 per cent. of the charge. This brass being limited in quantity and having been but once melted is assumed, in calculating the charge, to contain the original ingredient of 30 per cent. zinc. It is found that the introduction of a certain proportion of brass is useful in lowering the percentage of waste or loss from the melting. Thus, with new metals alone, this waste amounts to about 5 per cent. of the charge, but if the chargé contains over, say, 12 per cent. of brass, the waste is reduced to about 3 per cent. of the whole charge. This loss from oxidation depends largely upon the heating of the metal, so that it will be found in practice that there is a useful medium for the heat; if it is too high there is an over-waste of metal, and if too low there is danger of imperfect castings. The source of loss is frequently seen when the crucibles are skimmed before the pouring; globules and filaments of oxidized metal are drawn off with the dross.

In melting the charge, after the fire is well started, the copper is first introduced either alone or with some portion of the brass. As soon as the melting begins the surface is covered with charcoal, which is afterwards renewed one or more times before the charge is withdrawn. When the copper is all melted the spelter is introduced, each piece being taken with a pair of tongs and held well under the surface until melted; after this the remainder of the brass is put in to fill the crucible. The temperature of the metal having been considerably reduced by this, the crucible is left in the furnace until a proper heat is attained, which usually occurs in from tén to fifteen minutes. The copper requires from one and a half to two hours in melting, depending upon the heat of the furnace. When the crucibles are taken from the furnace the metal is carefully skimmed and then poured at once into the molds, which are arranged on a bench at a convenient height above the floor. Heavy weights are placed on the top of each mold to prevent expansion. There is no "riser" from the casting or sinking head other than the "gate," which serves only as an inlet and feeder, and has no value as a sinking head to produce pressure; and from the general soundness of the castings produced it may be judged that the present method is good.

An important feature in the treatment of the castings occurs at this point. The molds are opened in about five minutes after the casting, and while the sabots are still red hot they are thrown, *with the groove down*, into a barrel of cold water, the bottom of which is covered to some depth with sand. After a very brief interval the sabot is grasped with the tongs, raised, taken from the barrel, and placed in another vessel of water, with the object of keeping the water in the barrel cold. On raising the sabot from the sand as above a vacuum is created below, and this, with the steam generated within the groove, causes the core to be "blown out" from the groove with a distinct report.

The primary object of this treatment is to clean the groove, otherwise, if the castings were allowed to cool in the molds, the hard sand in the confined space of the groove could only be removed with difficulty. If the castings are exposed even for a short time to the air while hot they turn black, but by promptly placing them in water when taken from the mold a bright color is retained as would be if they were left to cool in the mold.

The treatment used undoubtedly causes a greater shrinkage than if the castings were allowed to cool in the molds, at the same time also it probably increases to a considerable degree the density of the metal. However, in the absence of specific experiments, its effect for good or ill can only be stated in general terms, and there is no evidence that the effect is otherwise than good. Castings treated in this way have been subsequently heated to a low red heat and struck heavy blows with a hammer; the metal gives and bends but does not crumble.

The finishing operations are done on two lathes, in each of which the piece requires to be mounted only once. In the first, the piece (sabot) is centered and clamped on the outside for, first, facing the base or forward face of the sabot and, second, cutting the screw-thread. In the second, the sabot is screwed upon a form fitted for the thread and length of the sabot, with the face previously finished brought up against a shoulder on the form or holder, in which position the exterior and the rear face of the sabot, including the groove, are finished. The workmen are provided with gauges for the thread and remaining dimensions. After the sabots are completely finished they are finally inspected and weighed.

Material and labor (omitting the preparation of the patterns and accessories for casting).—Each rough casting, including the "gate," weighs about 13.5 pounds, to which add 3 per cent. for waste, and we have 13.9 pounds of original metal required for each single casting, of which 9.7 pounds are copper, and 4.2 pounds zinc. The finished sabot averages about 9.625 pounds in weight. The difference, excepting the waste, and the "gate" which weighs about 1½ pounds and is remelted, is saved in the turnings, which can be best utilized for casting bearings, &c., for machinery.

One man working ten hours per day with a 22-inch or smaller lathe can finish in the first lathe 15 sabots per day, and in the second can finish 25 sabots per day. Including the labor of molding and casting, one experienced workman with one helper can turn out 20 sabots per day, which summarized gives for each sabot:

Metal:	Copper		9.7 pounds.
	Spelter		4.2 "
Labor:	Molding and casting.	One master-workman	30 minutes.
		One helper	30 "
	Finishing	One machinist (first lathe)	40 "
		One machinist (second lathe)	24 "

PLATE I.

PATTERNS AND MOLDS
USED IN CASTING
8-INCH BUTLER SABOTS
FOR
MUZZLE-LOADING PROJECTILES

Fig. 1.
PLAN AND SECTION
OF
UPPER PORTION OF CORE PATTERN

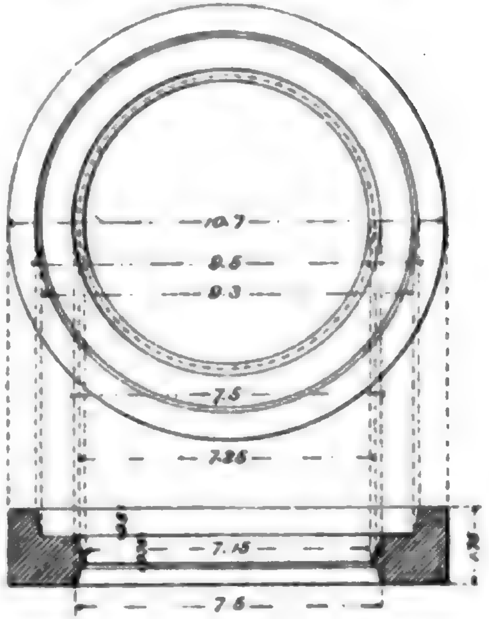


Fig. 2.
ELEVATION OF
LOWER PORTION OF CORE PATTERN
WITH
UPPER PORTION OUTLINED IN POSITION

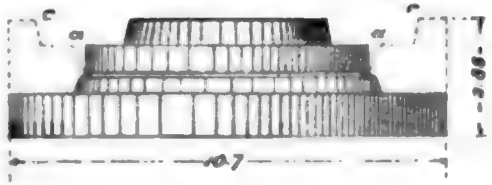


Fig. 3.
CORE SUSTAINING RINGS

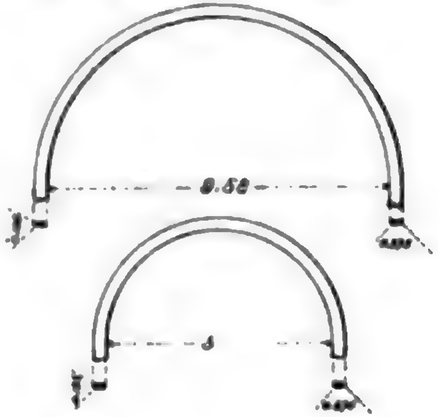


Fig. 4.
SECTION AND PLAN
OF
SABOT PATTERN

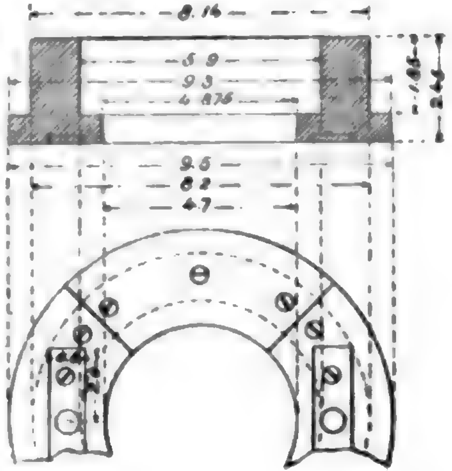
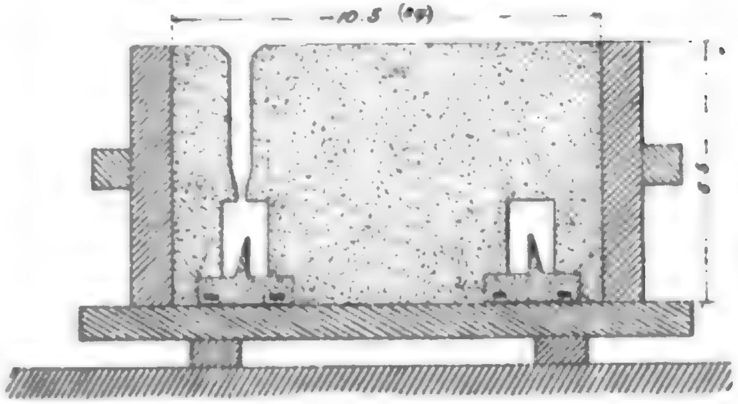


Fig. 5.
MOLD PREPARED FOR CASTING



Appendix 32a—1884.

APPENDIX 32b.

FABRICATION OF 8-INCH EUREKA PROJECTILES.

(2 plates.)

SIR: In accordance with your instructions I have the honor to submit the following short report on the fabrication, by the South Boston Iron Works, of 500 8-inch Eureka cored shot, contracted for under date of June 23, 1883.

The principal point noticeable is the great improvement made on the last few contracts, which is due not only to the fact that the company have received orders for projectiles at short intervals through the year, and thereby have been enabled to train their workmen, but also to their having acted on the suggestions made by the inspectors.

Their method may be briefly summarized as careful manipulation of the metal, suitable mixtures being first made in the reverberatory furnace, and afterwards remelted in smaller quantities in the cupola; the use of small ladles, by means of which the metal is quickly transported to the flasks, thereby avoiding any stiffening; drying the molds, instead of casting in green sand, with the result of obtaining cleaner shot, more free from blow-holes, &c.; the forming of a small cylinder on the point of the shot, by which shrinkage in length is provided for, and, finally, making the core pattern a little shorter than called for by the drawing. This is a new feature. In previous reports attention was called to the manner in which the projectiles tended to open in the prolongation of the core, due to the strains setting in from the direction of the head and walls, leading to the rejection of not a few. To overcome this the front end of the core-box (pattern) was filled in a little, a suitable shape being given to the surface, which, under the action of the stresses, assumed about the form and dimensions required by the contract drawings. Formerly the rejections for the cavity, being too long, were numerous, but among those just completed none were thrown out for this defect.

As the casting progresses it has been noticed that the cylindrical body tends to increase in length, caused, so the company think, by the absorption of water by the pattern and consequent swelling. As the cylindrical part of the pattern is of greater diameter than the base of the head, the sloping surface joining them seems to enlarge, causing the body to increase in length. As this takes place gradually, it cannot readily be allowed for in the original construction of the pattern. It would seem, however, if the pattern were turned approximately, then soaked in water, and afterwards brought to its true dimensions, this might be obviated, particularly if care was taken to keep it moistened when not in use. The better method, of course, would be iron patterns, which, except for standard projectiles, it would hardly be worth while making. Those intended for experiment only are usually ordered in small quantities and would not justify the increased cost.

Attention is also respectfully invited to there being no allowance in the base for sabot, though there is for every other part of the shot. The table of allowed variations provides for one of ±0.05 inch in length of base for sabot, which, in the case of a Butler projectile, where this is cylindrical, covers about the whole ground. But as, in the Arrick, this is a conical frustum, recessed for the studs on the sabot, an allowance in length alone hardly seems sufficient. In the corresponding parts of the sabot a variation of ±0.01 inch is permitted, and this, I think, should be likewise allowed in the base for sabot. These portions are annular surface joining conical base and cylindrical body, the "slope" of base and width and depth of recesses in it. In reference to the sabots they were almost perfect.

Mention should likewise be made of the more thorough inspection of the castings by the company before beginning the finishing operations, by which projectiles obviously unfit are at once thrown out instead of being turned, in the hope they might be accepted. No difficulty was experienced in obtaining the proper weights. In accordance with authority granted, a few weighing 183 pounds were accepted.

Inspection of all the projectiles cut up for specimens showed, both in the sides of the walls and the surface of the interior cavity, a perfectly sound shot, free from blow-holes or cavities of any kind. The opinion expressed in previous reports that the limits in this respect are sufficient. I see no reason to modify.

The success obtained is due to the care and watchfulness of all concerned, particularly to Messrs. Bainbridge and Woodworth, foremen of the foundry and machine-shops respectively. Tables giving results in detail are appended.

Very respectfully, your obedient servant,

HENRY D. BORUP,
Lieutenant of Ordnance, U. S. A.

SOUTH BOSTON FOUNDRY,
November 15, 1883.

PHYSICAL QUALITIES.

Date.	No. of casting.	Number cast.	Tenacity.	Specific gravity.	Hardness.
1883.					
September 5	1	15	27,410	7.2085	....
September 19	2	2	....	....	....
September 26	3	20	25,596	7.1801	....
October 9	4	16	27,015	7.1745	....
October 11	5	29	32,790	7.2541	9.31
October 13	6	30	31,124	7.2546	....
October 15	7	29	26,074	7.1860	....
October 17	8	30	25,727	7.2007	....
October 18	9	33	35,367	7.2811	....
October 19	10	34	38,703	7.1997	13.99
October 20	11	30	24,882	7.1968	....
October 22	12	34	28,710	7.1671	....
October 23	13	31	28,436	7.2012	....
October 24	14	30	28,579	7.1757	....
October 25	15	31	30,214	7.1822	13.33
October 26	16	30	34,098	7.2480	....
October 27	17	33	28,977	7.0086	....
October 29	18	31	32,715	7.2517	....
October 30	19	31	27,594	7.1889	....
October 31	20	32	26,836	7.2231	Fractured.

KIND AND QUANTITY OF IRON.

Date.	Remelted.	No. 1, shaparoon.	No. 2, Gridley.	No. 3, shaparoon.	No. 2, shaparoon.	Total.	Remarks.
1883.							
July 7	110	77	33	....	....	220.0	The weights are expressed in cwts. These charges are melted in a reverberatory furnace and run into pig, which is afterward remelted in the cupola. The number of pigs used depends on the quantity of iron required for other work as well as on that needed for the shot. No record, therefore, was kept of it.
July 13	103.4	....	70.4	46.2	....	220.0	
July 19	84	28.5	37 5	....	....	150.0	
July 25	100.5	20	20	....	....	140.5	
July 28	113.5	33.5	20.8	....	35	202.8	
Aug. 4	84.5	27.5	48	....	....	160.0	
Aug. 10	127.5	66	26.8	....	....	320.3	
Aug. 18	120	....	30.5	....	59	209.5	
Aug. 21	80	30	....	....	50	160.0	
Aug. 29	90	20	....	....	40	150.0	
Aug. 31	90	20	....	....	40	150.0	
Oct. 18	80	20	....	....	40	140.0	
Oct. 23	85	....	....	50	50	185.0	
Oct. 31	80	30	....	....	50	160.0	
Nov. 6	140	41.6	....	....	62.4	244.0	

Inspection report of 500 *8-inch ogival-headed Eureka cored shot for 8-inch muzzle-loading rifles, made for the United States Ordnance Department, by William T. Arrick, at Boston, Mass., under contract of the Chief of Ordnance, U. S. Army, dated June* 23, 1883.

Subject of measurement.	Prescribed dimensions.	Allowed variations.	
PROJECTILE.	*Inches.*	*Inch.*	*Per ct.*
Length of cylindrical portion of body	7.85	....	+ 2
Length of head	8.925	....	− 2
Length of base for sabot	2.05	±.05	....
Total length of projectile	18.825	....	1
Diameter of cylindrical portion	7.95	±.01	....
Diameter of base { in front	7.55	0	....
Diameter of base { in rear	7.25	0	....
Radius of head	12	±.05	....
Thickness of bottom	2.05	±.1	....
Length of interior cavity	10.10	±.1	....
Thickness of walls at 3.650 inches from base	2.225	....	....
Eccentricity of axis of interior cavity	0	.1	....
Diameter of (screw-plug) hole	1.5	±.01	....
Pitch of thread on fuze (or screw-plug) hole	8 per inch.		....
Length of thread on (screw-plug) hole	2.05	....	....
SABOT.			
Height of sabot	2.925	±.01	....
Exterior diameter of sabot	7.95	±.01	....
	Lbs. oz.		
Weight of sabot, mean	9 13	....	....
Weight of sabot and projectile	180 00	....	± 1

Number of 8-inch Eureka cored shot examined	544
Number rejected for erroneous dimensions of head	12
Number rejected for erroneous dimensions of cylindric body or base	15
Number rejected for erroneous dimensions of interior cavity	2
Number rejected for eccentricity of interior cavity	2
Number rejected for defects in material or finish	13
Total number rejected	44
Total number accepted	500
Weight of heaviest one accepted with sabot	183
Weight of lightest one accepted with sabot ..lbs..	178
Weight of total number accepted ..do..	85,462.4
Mean weight of projectile ..do..	170.9
Number of sabots examined	503
Number of sabots rejected for erroneous dimensions	1
Number of sabots rejected for defects in material or finish	2
Total number of sabots rejected	3
Number of sabots accepted	500
Weight of total number accepted ..lbs..	4,913.6
Mean weight of sabot ..do..	$9\frac{13}{16}$
Weight of total number of shot and sabots accepted ..lbs..	90,376

PHYSICAL PROPERTIES.

Specimen.	Density (actual).	Tenacity (actual).	Hardness (unit of measure=.1 inch).
Maximum	7.2811	35,367	15.05
Minimum	7.0086	24,882	9.31
Mean	7.1962	29,126	12.92

* REMARKS.—Awaiting transportation to the Watertown Arsenal, 480; to Lieutenant Birnie, Cold Spring, N. Y., 10; previously sent to Sandy Hook, 10.

I certify that I have carefully inspected the above-noted projectiles and that they conform to the dimensions prescribed within the variations allowed; and, further, that the terms of the contract as to material and workmanship have been complied with in their manufacture.

D. A. LYLE,
Captain of Ordnance, Inspector.

Date of inspection, November 10, 1883.

NOTES.—* State to what points projectiles were shipped, &c.

The exterior diameter is verified by means of gauges; the high gauge is 0.02 inch over, and the low gauge is 0.02 inch less, than the prescribed diameter. The diameter of the cylinder gauge is the same as that of the high gauge. Eccentricity is proven by rolling the projectiles on level iron rails, and is determined in amount by means of the calipers for measuring the thickness of the walls. The form and dimensions of the head of the projectile and of the cannelure and outer lip of the sabot are verified by means of templets.

The other dimensions of the sabot, and those corresponding thereto upon the base of the projectile, are verified by the "sabot gauges." The presence of cavities on the interior is ascertained by means of the "searcher"; the depth should not exceed 0.2 inch. The weight should be stamped on each projectile.

PROJECTILES.

Cast	686
Used for tests	25
Finished	548
Inspected	544
Accepted	500
Surplus for possible rejections	4
Before finishing	113
Rejected after finishing:	
Erroneous dimension of head	12
Erroneous dimension of cylinder or base	15
Erroneous dimension of interior cavity	2
Eccentricity	2
Weight	0
Defective material	13
Total	44
Weighing 178 pounds	2
Weighing 179 pounds	45
Weighing 180 pounds	154
Weighing 181 pounds	190
Weighing 182 pounds	97
Weighing 183 pounds	12

SABOTS.

Inspected	503
Rejected	3
Defective material	2
Erroneous dimensions	1
Accepted	500
Total number cast	532
Weighing 9 pounds 4 ounces	1
Weighing 9 pounds 6 ounces	1
Weighing 9 pounds 7 ounces	4
Weighing 9 pounds 8 ounces	7
Weighing 9 pounds 9 ounces	13
Weighing 9 pounds 10 ounces	17
Weighing 9 pounds 11 ounces	25
Weighing 9 pounds 12 ounces	49
Weighing 9 pounds 13 ounces	68
Weighing 9 pounds 14 ounces	99
Weighing 9 pounds 15 ounces	72
Weighing 10 pounds	58
Weighing 10 pounds 1 ounce	41
Weighing 10 pounds 2 ounces	27
Weighing 10 pounds 3 ounces	7
Weighing 10 pounds 4 ounces	6
Weighing 10 pounds 5 ounces	2
Weighing 10 pounds 6 ounces	1
Weighing 10 pounds 7 ounces	1
Weighing 10 pounds 8 ounces	1

WEST POINT FOUNDRY,
Cold Spring, N. Y., December 11, 1883.

The CHIEF OF ORDNANCE, U. S. ARMY,
Washington, D. C.:

GENERAL: The following report respecting a comparative examination of ten 8-inch Eureka cored shot from the South Boston Iron Works, and a similar number from the West Point Foundry, made under contract of June 23, 1883, with recommendations as to the establishment of a standard 8-inch Eureka cored shot, is respectfully submitted pursuant to instructions contained in your letter of November 13, 1883.

The examination was made at the West Point Foundry November 30, 1883, and included the following observations:

1. Weight of the shot on one and the same scale, a Fairbanks No. —, capable of weighing about 500 pounds.
2. Exterior dimensions of the shot.
3. Dimensions of the core of shot.
4. Specific gravity and tenacity of the metal.

The result of the first two observations showed the two lots of shot to be of practically the same exterior dimensions, and that the weights marked upon each shot at the time of its original inspection were correct, in each case to within one-half pound; that is, no greater difference than this was observed. It may be remarked here that it is the practice at both foundries to mark these projectiles to the nearest full pound.

In regard to the dimensions of core, an examination of all the shot showed what has been already reported, viz, that those made at South Boston, which we will call lot B, contained the original core given in drawing accompanying contract (Plate I), and that those made at the West Point Foundry, which we will call lot P, contained the larger, or second model, core given in drawing issued from Ordnance Office October 10, 1883 (Plate II). In order, however, to ascertain accurately the dimensions of core and to obtain specimens for density as nearly as possible from the middle of casting, two projectiles of very nearly equal weight, one from each lot, were selected and dismantled. In these the cast iron alone weighed as follows: Shot from lot B, 168.5 pounds; shot from lot P, 168.75 pounds. These two shot were then cut through, perpendicular to the axis, at four inches from base; that is, through the maximum circumference of core nearly. Wooden templets were then fitted accurately to the two separate parts of the cores, allowance in length being made for the width of cut, which was 0.3 inch. An outline of these templets when compared with the original drawings showed that in each case the actual core was larger, especially near the point, than its construction drawing; also that the core of shot P was more enlarged than that of shot B. This enlargement of core is believed to be due principally to the shrinkage of the metal upon casting, and the greater enlargement of P is supposed due to the greater hardness and density of its metal, carrying with these qualities a greater tendency to shrinkage.

To obtain specimens for density and tenacity a short bar was cut, with a hollow boring tool, in the direction of axis of shot, from the side wall of each of the forward portions of the two samples. From these bars tenacity specimens of the usual dimensions were prepared. The tests gave—B: Density, 7.0936; tenacity, 19,085 pounds. P: Density, 7.2438; tenacity, 31,601 pounds.

The tenacity shown by B was phenomenal, being much below that of any specimen tested during the casting of all the shot under the contract. If, therefore, any weight at all be attached to the result it will simply be available in noting that iron of this density cannot always be relied upon to give the tenacity required for these shot; that is, 25,000 pounds. The density obtained from sample B is below the average of the South Boston shot; that obtained from sample P is very nearly the average of the West Point Foundry shot. (See tabular statements of densities, tenacities, and weights, herewith attached, marked A and B.)

Limiting ourselves now to the two sample shot which were carefully weighed and examined, it becomes apparent how the weights were the same although different cores were used. Assuming dimensions other than the cores to be the same, we find—

Sample shot B: Density, 7.0936; weight, 168.5.

From which we find:

$$\text{Solid contents} = \frac{\text{weight of cast-iron}}{\text{weight of cubic inch for density of 7.0936}} = \frac{168.5}{0.256043} =$$

656.58 cubic inches.

And sample shot P: Density, 7.2438; weight, 168.75.

$$\text{Solid contents} = \frac{168.75}{0.261464+} = 645.41 \text{ cubic inches.}$$

That is to say, the solid contents in P are shown to be 11.17 cubic inches less than in B, but the difference in density makes up the weight. By computation from the original drawings the two cores differ in contents by 10 cubic inches. But this discrepancy here shown (1.2 cubic inches) is undoubtedly due to the relatively greater enlargement of the core of P in casting.

CONCLUSIONS.

Experience has shown that 7.2 is a safe average density to assume for cast iron having a tenacity of 25,000 pounds per square inch. In fixing the standard dimensions for this projectile we therefore proceed to find the dimensions which will give a projectile weighing 180 pounds with metal of this density. Taking the cubical contents of sample shot P, which we have already determined practically to be 645.41 cubic inches, we find: Weight = cubical contents × weight of cubic inches for density of $7.2 = 645.41 \times 0.259883 = 167.72$ pounds, and adding to this weight of cast iron the known weight of sabot and base plug, we have: Weight of cast iron = 167.72; weight of sabot = 10.54; weight of base plug = 1.85; total weight, 180.11 pounds—showing that this projectile is practically of the required dimensions.

Assuming now that projectiles when made can be finished to the exact dimensions of drawing—since this feature is, within small limits, under control, whilst the density of the iron is not—we further find that with these dimensions of shot the density may be allowed to vary between limits of 7.13 and 7.27 and yet keep within a limit of 1 per cent. of the standard weight; for the former the finished shot would weigh 178.49 pounds, and for the latter 181.75 pounds.

RECOMMENDATIONS.

We recommend as standard the drawing lately used in the construction of these projectiles at the West Point Foundry, and that the standard tenacity be 25,000 pounds per square inch. In regard to limits of weight, we recommend from −1 per cent. to +1½ per cent. of the standard 180 pounds, the higher limit being greater than the lower; since if it were not so, that is, if the density of metal be limited to 7.27, it would at times result in rejecting shot for overweight which would be in other respects of excellent quality. It is at the same time considered that a limit of more than + 1 per cent. will seldom be needed, otherwise a slightly higher average density would have been assumed in connection with a slight reduction in cubical contents of shot. These limits are believed to be alike favorable to the Government and to the founders.

We further recommend that the number of projections on interior of sabot be fixed at three (3), as the most suitable number to prevent any canting of the sabot in transportation or in loading.

R. BIRNIE, JR.,
Lieutenant of Ordnance.
H. D. BORUP,
Lieutenant of Ordnance.

ORDNANCE OFFICE,
December 18, 1883.

The foregoing recommendations in regard to dimensions of 8-inch Eureka projectiles for muzzle-loading rifles are approved.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

ADDENDA A.

Density and tenacity of metal, and weight of 8-inch Eureka cored shot made at the Sout Boston Foundry, under contract dated June 23, 1883.

Date.	Number cast.	Tenacity.	Density.	Remarks.
Sept. 5	15	27, 410	7. 2085	
Sept. 19	2	....	....	178 = 2
Sept. 26	20	25, 596	7. 1801	179 = 45
Oct. 9	16	27, 015	7. 1745	180 = 154
Oct. 11	29	32, 790	7. 2541	181 = 190
Oct. 13	30	31, 124	7. 2546	182 = 97
Oct. 15	29	26, 074	7. 1860	183 = 12
Oct. 17	30	25, 727	7. 2007	
Oct. 18	33	35, 867	7. 2811	Total 500
Oct. 19	34	38, 703	7. 1997	Mean, 180. 7 pounds.
Oct. 20	30	24, 882	7. 1968	
Oct. 22	34	28, 710	7. 1671	
Oct. 23	31	28, 436	7. 2012	
Oct. 24	30	28, 579	7. 1757	
Oct. 25	31	30, 214	7. 1822	
Oct. 26	30	34, 098	7. 2480	
Oct. 27	33	28, 977	7. 0086	
Oct. 29	31	32, 715	7. 2517	
Oct. 30	31	27, 594	7. 1889	
Oct. 31	32	26, 836	7. 2231	

ADDENDA B.

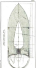
Density and tenacity of metal, and weight of 8-inch Eureka cored shot made at the West Point Foundry, under contract dated June 23, 1883.

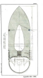
Date.	Castings.—No. of shot.	Metal.		Remarks.
		Density.	Tenacity.	
1883.				
Sept. 12	16	7. 2278	25, 794	Cast with original core. Specimens taken from base of shot. Sixty-six shot were accepted with this core, of which four weighed 183, four 184, thirty-two 185, and twenty-six 186 pounds. Average weight, 185.23 pounds.
Oct. 4	33	7. 2492	28, 604	
Oct. 5	34	7. 2792	27, 996	
Oct. 22	48	7. 2572	28, 633	Cast with core given in drawing issued from Ordnance Office October 10, 1883. Specimens taken in each case, except for October 22, from point of shot. Shot cast with second model core: 183 pounds = 28 182 pounds = 189 181 pounds = 179 180 pounds = 30 179 pounds = 2 178 pounds = 1 Total number.. 429 Average weight, 181.5 pounds.
Oct. 24	52	7. 2438	28, 530	
Oct. 25	47	7. 2422	30, 109	
Oct. 26	48	7. 272	30, 171	
Oct. 27	49	7. 2718	29. 410	
Oct. 29	48	7. 2613	29, 392	
Oct. 30	49	7. 2433	26, 838	
Oct. 31	48	7. 2518	26, 982	
Nov. 1	62	7. 2351	27, 533	
Means.	.....	7. 2529	28, 334	

NOTE.—The ten shot sent to Sandy Hook for firing proof are not included under head of remarks. All shot were made with metal taken direct from air furnace and cast with base up.

R. BIRNIE, JR.,
Lieutenant of Ordnance, Inspector.

WEST POINT FOUNDRY,
Cold Spring, N. Y., December 11, 1883.





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APPENDIX 33.

REPORT OF MANUFACTURE OF 3.2-INCH BREECH-LOADING STEEL RIFLE AT WATERTOWN ARSENAL.

BY MAJ. F. H. PARKER, ORDNANCE DEPARTMENT.

(14 plates.)

DESCRIPTION OF THE GUN FINISHED.

The gun as designed by the Ordnance Board is shown in the Report of the Chief of Ordnance for 1883, page 289, Plate I, and in Fig. 1, Plate XI. Various changes and modifications have been made in the plans during the progress of the work, with the approval of the Ordnance Board, and these will be indicated further on.

The gun as finished is represented in Plate I, Fig. 1. It is made entirely of low steel, all the parts except the tube being tempered in oil, and is composed of the following parts, viz:*

1. An interior tube, whose total length is 85.20 inches. The exterior of this tube for a distance of 19 inches from the rear end is turned to a diameter of 6.009 inches. From the extremity of this distance it is turned to a diameter of 5.608 inches for a length of 24.70 inches, thus forming a shoulder 0.2005 inches in depth. Continuing for a distance of 3 inches a thread is cut for the key-ring, the pitch of thread being 0.26 inch, diameter through tops of threads 5.58 inches, through bottoms 5.32 inches, making the height of thread 0.13 inch, and allowing a play of 0.014 inch for screwing home of key-ring. For a distance of 1 inch from end of thread the diameter of the tube is 5.20 inches. On this the end of key-ring rests when screwed home, so as to form a tight joint. From this point the tube tapers for a distance of 36 inches to a diameter of 4.6 inches, where it joins the muzzle-collar (whose diameter is 5.10 inches and length 1.5 inches), by a curved surface whose radius is 0.64 inch. Fig. 6, Plate I, shows details of screw-thread for key-ring.

On the interior of the tube, beginning at the rear, the diameter for a distance of 0.6 inch is 3.48 inches, and this part of the tube was afterwards given a very slight taper, to correspond with that on the gas-check, for which this portion of the tube is the seat. From the end of this distance the interior diameter is 3.40 inches, for a distance of 1.4 inches. Then begins the elliptical powder-chamber, whose length is 10 inches and maximum diameter 3.8 inches. It is a frustum of an ellipsoid whose major axis is 22.8 inches and minor axis 3.8 inches. At the end of the powder-chamber the shot-chamber begins. The diameter of powder-chamber at the end next shot-chamber is 3.4 inches. From this point there is a straight taper for a distance of 0.2 inch to a diameter of 3.32 inches. This diameter extends for a distance of 1.475 inches along the axis of tube, and then there is another straight taper for a distance of 0.2 inch to the bottom of grooves 3.30 inches diameter, and to the top of lands 3.20 inches diameter. The lands are therefore joined to the extremity of shot-chamber by a bevel of 0.06 inch in a distance of 0.2 inch. From this point the rifling extends to the muzzle. Number of grooves, 24; number of lands, 24; width of grooves, 0.3 inch; width of lands, 0.1188 inch; depth of grooves, 0.050 inch; twist, one turn in 30 calibers. The junction of lands and grooves is rounded with a curved surface of 0.05 inch radius. The details of shot-chamber are given in Plate I, Fig. 3.

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* These parts are given in detail in Plate II: Fig. 1, the tube; Figs. 2, 2*a*, 2*b*, 2*c*, the jacket; Figs. 3, 3*a*, 3*b*, the trunnion-ring; Figs. 4, 4*a*, the sleeve; Figs. 5, 5*a*, the key-ring; Figs, 6, 6*a*, the base-ring.

2. A jacket, which is shrunk on the rear portion of the tube and projects over the rear end of tube 5.6 inches. It is in contact with the tube for a length of 22.85 inches, measured along axis, and its total length is 28.45 inches. A section through its axis gives for its exterior a curve approaching an ellipse, whose maximum ordinate at the middle is 4.78 inches, while at the rear, at a distance of 12 inches from the middle, this ordinate is 4.11 inches; at the front, at a distance of 14 inches from the middle, this ordinate is 3.87 inches. The intermediate points are connected by a curve, as before mentioned. At a distance of 1.25 inches from the forward end of the jacket a tapering shoulder is turned, and a corresponding one on the trunnion-ring. This shoulder on trunnion-ring hooks over that on the jacket, and holds the jacket and trunnion-ring together. The diameter of the shoulder next the jacket is 6.559 inches, and at the forward end next the trunnion-ring 6.602 inches, thus giving a taper from rear to front of 0.0215 inch in a distance of 1.25 inches. The taper is joined to jacket with a curve of 0.1 inch radius, and terminated at its forward end with a curve of 0.25 inch radius (details in Plate I, Fig. 4). The rear end of jacket is rounded with a curve of 0.4 inch radius. On the interior of the jacket, beginning at the rear, the surface is rounded with a curve of 0.4 inch radius. It then tapers for a distance of 1.2 inches from a diameter of 6.55 inches to a diameter of 6.35 inches, forming a seat for the carrier-ring. It is then for a distance of 0.2 inch straight, and 6.35 inches in diameter, forming a seat for the blank end of base-ring; then for a distance of 3.8 inches a square-shouldered screw-thread is cut in it for the reception of the base-ring. The details of this thread are given in Plate I, Fig. 2. The hinge for carrier-ring is cut out of the rear portion of this jacket. Its details and those of the jacket are shown in Plate II, Figs. 2 and *2a*. The jacket for a length of 19 inches from the end of this thread is bored to a diameter of 6 inches. At the end of this distance is the shoulder, and from this point to the forward end the interior diameter is 5.6 inches for a distance of 3.85 inches.

3. A trunnion-ring, which has a shoulder corresponding to that on the jacket, and of the following dimensions: Length, 1.25 inches; diameter next to jacket, 6.55 inches; next to trunnion-ring, 6.5928 inches, giving a taper of 0.0214 inch in this distance of 1.25 inches. The diameter of ring for the rest of its length (7.55 inches) is 5.6 inches. The diameter of the trunnions is 3.8 inches, and of the rimbases 4.8; height of each trunnion, 2.8 inches; total width of trunnion-ring from out to out of trunnions 15.1 inches. The other details relating to trunnions are shown in Plate II, Figs. 3, *3a*, *3b*.

4. A sleeve, which is shrunk on next to the trunnion-ring. Its length is 13.30 inches; exterior diameters, 6.60 inches next to trunnion-ring, and

6.50 inches next to muzzle; interior diameter, 5.6 inches (details shown in Plate II, Fig. 4).

5. A key-ring, screwed on in front of sleeve and holding the other parts of the gun in place to prevent any forward movement. It is 3 inches long, 6.50 inches exterior diameter, and the details of its screw-thread are shown in Plate II, Fig. 5. The only point about it especially worthy of note is, that at the front end the screw-thread stops at a distance of about 0.2 inch, and this portion of the ring is bored to a diameter of 5.2 inches, so that on being screwed home on the tube this portion of it rests on the tube in front of the screw-thread, and forms a tight joint.

6. A base-ring, screwed into the rear of the jacket. On its exterior surface is cut the square-shouldered thread corresponding to that already mentioned on the interior surface of jacket, and on its interior surface is cut the interrupted thread into which the breech-plug is screwed in firing. The front surface of this base-ring fits closely against the rear of the tube, a tight joint being secured by shrinking it into place. Against its rear end the carrier-ring has a bearing when in position for firing. The length of this base-ring is 4 inches; exterior diameter, 6.35 inches; interior diameter, 4.47 inches to bottom of slots, 4.03 inches to tops of threads. The details of the threads, &c., are shown in Plate II, Fig. 6.

The thickness of metal at maximum diameter of powder-chamber is 2.88 inches, and it varies from that point to the neck behind muzzle-band, where it is 0.7 inch thick. Weight of gun complete, 791.25 pounds; preponderance 77 pounds 11 ounces.

THE BREECH MECHANISM.

This is composed of the following principal parts, viz:

a. The breech-block.
b. The Frèire obturator.
c. The carrier-ring.
d. The lever-handle.
e. The bronze or fixed handle.
f. The hinge-pin.
g. The latch-pin.
h. Stops on the carrier-ring.

And certain smaller parts, whose uses will appear in the description

a. The breech-block, is shown in Plate III, Figs. 1, 2, 11, 12, and 15. Its total length is 5.95 inches. It is threaded for a distance of 4 inches from its forward end, and the circumference of the thread is divided into six equal parts, the alternate ones being planed off, and giving the interrupted screw, which is well known. Besides these blank sectors, two additional longitudinal grooves are planed in two of the blank sectors in which slide the stops of the carrier-ring. One of these grooves is shown at *a*, *a* (Plate III, Fig. 2), and at *a*, *a* (Plate III, Figs. 11 and 12). The length of these grooves is 4.55 inches, width at bottom 0.75 inch, and their sides are planes passing through axis of plug. They are 0.4 inch in depth, measured from the top of threads on plug, and 0.22 inch below bottoms of threads. These grooves stop at a distance of 0.2 inch from the front end of plug, leaving a shoulder of metal of this thickness, against which the stops of carrier-ring bear when the plug is withdrawn. At the rear end of plug these grooves are cut out, as shown in Plate III, Figs. 2 and 11, corresponding to the pitch of the thread, and of a width equal to that of the stops, viz, 1.01 inches, and of a length equal to one-sixth of a turn of the plug. This is in order that the stops which rest in the longitudinal grooves before described, and which slide in them when the plug is pushed forward through carrier-ring, may turn in these transverse grooves, when the plug is revolved one-sixth of a turn, to lock it into its threads in the base-ring. At *b* and *b* (Plate III, Figs. 2 and 15) is shown another groove, whose shape is given in section at *b* (Plate III, Fig. 15). In this groove slides the end of the latch-pin, which locks the carrier-ring to jacket and unlocks it automatically by the action of this groove and a spring. The interior of the breech-plug is bored out for a distance of 2.938 inches to a diameter of 1.4 inches, measuring from the front end of plug. From the extremity of this distance for a length of 2.217 inches the diameter is 0.7 inch, and then for a distance of 0.75 inch the diameter is 1.3 inches. This is for the reception of the spindle of the Freire obturator, with its spring and locking-nuts. At the rear end of plug is a projecting lug for the lever-handle. These details are shown more clearly in Plate III, Fig. 15.

b. The Freire obturator.—This is described in Ordnance Notes No. 292, but as used in the 3.2-inch gun it differs in some respects from the former. It is shown in Plate III, Fig. 15. Its parts are: a spindle, with its head, the latter a truncated cone; an expanding gas-ring, fitting the head; a spiral spring; two locking-nuts, and a copper bushing at the forward part of vent. The arrangement is shown in drawing. The vent, 0.2 inch in diameter, passes through the axis of spindle, and the copper bushing is inserted by pressure at the front end. The spiral spring presses the spindle forward, when relieved from the pressure of the powder-gas, allowing gas-ring to contract to its original dimensions. The spindle is held in rear by two check-nuts, by means of which any degree of expansion can be given to the ring by drawing back the spindle. The gas-ring fits accurately against the face of the breech-plug, and has a play of 0.01 inch between its exterior surface and that of its seat. The head of the spindle also has a play of 0.17 inch between its interior face and the front surface of the breech-plug. The junction of gas-ring and head of spindle is ground accurately. The action of the gas-check is as follows: The pressure of the powder-gas when the gun is fired, acting on the cup-shaped head of the spindle, drives it (and the whole spindle) back, compressing the spiral spring, and at the same time by its wedging action on the gas-ring expanding the latter till it fits accurately on its seat, thus preventing any escape of gas. When the pressure is removed the action of the spring forces the spindle forward, and the gas-ring contracts and resumes its former position. By setting up the nuts at the rear end of the spindle gas-ring is expanded, and its play decreased.

c. The carrier-ring.—This is shown in Plate III, Figs. 3 and 4, and at *a* (Plate III, Fig. 1), and also in section at *a′*, *a′* (Plate III, Fig. 2). It forms a support for the breech-plug when the latter is withdrawn from its position in the breech and is swung round to open the breech for loading. Its interior diameter is 4.47 inches, and its exterior is a frustum of a cone, forming a surface which fits accurately in its seat at the rear of the jacket, previously described. *c c′* are the lugs (Fig. 4), which fit into corresponding recesses in the jacket, and form a hinge, on which the carrier-ring and its breech-plug are swung back in loading. *b*, *b′* (Fig. 1) and *b* (Fig. 4) are the stops, which are fitted into the carrier-ring, and which slide in the grooves before mentioned in the breech-plug, and guide it while it is being drawn out from its seat, and hold the plug when the carrier-ring is swung back. *a* (Fig. 4) is the latch-pin, which locks the carrier-ring to the jacket at a certain period of the movement of the breech-plug. This latch-pin enters a corresponding hole in the interior of the jacket. It is shown at *a* (Fig. 4, Plate III), and its details are shown in Figs. 6 and 7, Plate III. It is composed of the following parts: a pin (Fig. 7); a spiral spring (Fig. 4); a rectangular head (Fig. 6); and a screw-plug, *d* (Figs. 4 and 6), with a rectangular slot for the reception of the head (Fig. 6); this head is secured to the pin by a screw through *a* (Fig. 6). The connection of the different parts of the latch-pin is shown in Fig. 4, Plate III. The pin is first inserted in the hole drilled for it in the carrier-ring; the spring is then dropped into place, resting on the shoulder at the bottom of pin; the screw-plug with the rectangular opening is next inserted and secrewed home; the pin is then pushed up from the inside, compressing the spring, and the rectangular head put on and secured by its screw. It will be seen from the drawing that the action of the spring is to press down the latch and unlock the carrier-ring, and hence the locking can only be accomplished by pushing up the pin from the inside. This is accomplished in the gun by the peculiar shape given to the groove in which the pin moves. *x* (Fig. 4) is a recess, into which the head of the lever-handle fits when the breech-plug is in the firing position, by which the plug is locked, and prevented from turning. It is shown in section in Fig 5, Plate III. Fig. 8, Plate III, is the screw for securing the stops in carrier-ring.

d. The lever-handle, is shown in Figs. 13 and 14, Plate III. Its head at *a* forms a cam, which fits into a recess in the face of the carrier-ring already described. Its edges at *b* are slightly beveled to correspond with the sides of its recess. The object of this is, when the threads are first fitted, if there is any slight inaccuracy in their cutting, the block cannot be screwed entirely home, and this beveled surface allows for the inaccuracy. Again, after firing, when the threads all fit accurately and come to a bearing, the plug on being screwed home will pass a little beyond its proper position. The beveled surface acting on the opposite side will then bring the plug back to its proper position when the lever-handle is lowered. The lower end of the lever handle is rounded, and when the plug is in its firing position this rounded end fits in a recess cut in the rear portion of jacket, and shown at *c* (Fig. 1, Plate III). Thus the plug is held by the lever-handle resting at one end in a recess in the carrier-ring and at the other end in this recess in the jacket, and the block (or plug) cannot turn till the lever-handle is raised.

e. The bronze or fixed handle.—This is shown in Figs. 1 and 2, Plate III, at *h* and *h*. It is attached to the rear of the breech plug by two tap bolts, and serves as a hold for the hand in withdrawing the breech-plug from its seat.

f. The hinge pin, which is shown at *k* (Fig. 1, Plate III).—Its use is obvious.

g. The pin for lever-handle, shown at *k′* (Figs. 1 and 2); *h*, stay-pin for pin of hinge and *n*, *n*, same for pin of lever-handle (Fig. 1, Plate III). They hold the above-named pins in position.

h. The stops on carrier ring, are shown in detail in Figs. 9 and 10, Plate III. Their length measured along the axis of the gun is 1 inch, to give as long a bearing as possible for the grooves of the breech-plug. They are bored out for a distance of 0.2 inch, measuring from the exterior surface, in order that the rear end of the breech plug, which is without a thread, may enter for this length into the carrier-ring and completely fill the ring, and thus avoid openings into the interior, through which dust, &c., might penetrate and injure the parts.

ACTION OF THE BREECH MECHANISM.

To understand the action of the different parts composing the breech mechanism, suppose the breech closed and the piece ready to fire. The lower rounded end of the lever-handle then rests in its spherical recess in the lower part of the jacket *c* (Fig. 1, Plate III), while the head of the lever-handle rests in its recess in the face of the carrier-ring *x* (Fig. 1, Plate III), thus locking the breech-plug in its position in the base-ring. and rendering impossible any rotary movement of the breech-block in firing.

The groove for the inner end of the latch-pin, shown at *b* and *b* (Fig. 2, Plate III), is of the following shape and dimensions: Starting at *a* (Fig. 2, Plate III), its depth is 0.165 inch below the surface of the blank sector of breech-plug, and this depth continues for a distance toward the front of breech-plug of 3.64 inches; from this point it inclines to a depth of about 0.25 inch, as shown at *b′* (Fig. 15), for a distance of 0.5 inch; it then terminates in a cavity of the shape shown at *b″* (same figure). Now, returning to the point *a*, where the longitudinal groove just described starts, the transverse groove shown at *b* (Fig. 2, Plate III), gradually increases in depth from this point of beginning to the end of the groove at *c* (Fig. 2, Plate III), where its depth is the same as at *b″* (Fig. 15, Plate III), viz, 0.315 inch. The length of this transverse portion of the groove is one-sixth of a turn.

The inner end of the latch-pin at *a* (Fig. 4, Plate III) is shaped to fit into the cavity at the forward end of the longitudinal groove at *b″* (Fig. 15, Plate III). This latch-pin has to rise about 0.13 inch, in order to lock into the recess in the interior of jacket, and the dimensions of the groove in which it bears are so arranged that while the inner end of the pin is resting on the straight portion of the groove from *b* to *b′* (Fig. 15, Plate III), this pin is pushed up through the carrier-ring, and the carrier-ring locked to the jacket. When the end of the pin begins to descend the incline *b′ b″* the spring of the pin begins to withdraw it, and unlock the carrier-ring, and, finally, when the pin rests in its cavity *b″* (Fig. 15, Plate III), at the end of the longitudinal groove, the carrier-ring is unlocked, and ready to be swung back on its hinge, and the pin is held firmly in its cavity by the spring. In the same way, when the end of the pin is made to move from *a* to *c* (Fig. 2, Plate III), the depth of the groove gradually increasing, the spring gradually withdraws the pin till at the extremity *c* of the transverse groove the carrier-ring is again unlocked, and the pin pressed down to the bottom of the groove. It will be seen, then, that the carrier-ring is unlocked when the pin rests in the two positions *b″* and *c* at the ends of the groove, and that it is locked in every other position of the pin in its groove.

This being understood, when the breech-plug is in the firing position, with its lever-handle locked, as before explained, the lever handle is vertical, the plug is pushed forward through the carrier-ring, and base-ring, and its threads locked into the corresponding threads of the base-ring; the gas-check is in position at its seat, and the inner end of the latch-pin is resting at the extremity *c* (Fig. 2, Plate III), of its transverse groove. The two stops on the carrier ring also rest at the extremities of their transverse grooves at *dd* (Figs. 2 and 11, Plate III). Now, in this position, the end of the latch-pin resting at *c* (Fig. 2), the carrier-ring is unlocked from the jacket. and therefore during firing there is no strain on the carrier-ring, except that which may arise from the effort of the breech-plug to rotate, and from the manner of its locking this strain will be practically nothing. The carrier-ring is kept closed during firing by the lug of the lever handle.

After firing, to open the breech the lever handle is raised till its axis is parallel to that of the piece. This movement raises the rounded end of the lever-handle from its recess in the jacket, and at the same time causes the head of the lever-handle to move entirely out of its recess in the face of the carrier-ring, thus unlocking the breech plug, and allowing it to be turned. Keeping the lever-handle in this position, and by means of it and of the fixed bronze handle the breech plug is now turned to the left one-sixth of a turn, till the stops on the carrier-ring bring up against the sides of their grooves at *d′ d′* (Figs. 2 and 11, Plate III), when the movement will be arrested. By this movement (one-sixth of a turn) the threads on the screw-plug are released from their bearings against the corresponding threads of the base-ring, and are brought into the blank sectors of the base-ring. While this movement of the screw-plug is taking place, the inner end of the latch-pin is made to move along the bottom of the inclined groove from *c* to *a* (Fig. 2, Plate III), and the groove being more shallow at this latter point, as explained, pushes up the latch-pin, and locks the carrier-ring to the jacket. The lever-handle is now depressed as far as possible, and by this movement its cam-shaped head comes to a bearing against the rear face of the carrier-ring, and forces the breech-plug backward out of the piece for a short distance. The object of this, it is apparent, is to loosen the contact between the parts and overcome any sticking that may occur, by the powerful action of the cam and lever. The breech-block in position ready for withdrawal is shown in Fig. 1, Plate III.

The breech-block being in this position, and the carrier-ring locked to the jacket, so that it cannot be pulled open, the breech-block is then pulled out through the carrier-ring, the hand grasping the fixed bronze handle.

During this movement of the block to the rear the stops in the carrier ring slide in their respective grooves, till at the end of their travel they bring up against the shoulders in the breech-block at the front ends of the grooves.

During this same movement the end of the latch-pin of the carrier-ring travels in its groove, and being of the same depth up to the point *b′* (Fig. 15, Plate III), the carrier-ring is kept locked to the jacket during this travel. But as the end of the latch-pin begins to descend along the incline *b′ b″* (Fig. 15, Plate III), the spring acting on this pin withdraws it from its recess in the jacket. Finally, when the breech-plug is drawn out to its full extent, and the stops on the carrier-ring come to a bearing against the shoulders in their grooves, the end of the latch-pin drops into its cavity at the end of its groove, and the carrier-ring is unlocked and free to swing with the breech-plug around its hinge.

The carrier-ring and plug are then swung around to the left, and the breech is open, and the piece ready for loading.

It will be seen, therefore, that during the firing the carrier-ring is unlocked, and there is no strain on it, but as soon as the breech-plug is turned for withdrawal the carrier-ring becomes locked, and remains so during the withdrawal of the plug, and as soon as the plug is drawn out to its full extent the carrier-ring becomes unlocked and ready to be swung back.

The charge and projectile having been inserted, the next step is to close the breech for firing. The shape of the recess in the plug which receives the end of the latch-pin has been described. In swinging round the carrier-ring and its breech-plug to close the breech it is important that the breech-plug shall not move forward through the carrier-ring till the latter has reached its proper seat, otherwise the gas-check would jam against some part of the gun, and probably be seriously injured. To guard against this forward movement of the breech plug prematurely, the recess at the end of the latch-pin groove has been given its present shape. With the pin seated in this recess and held there by the action of a stiff spring, any forward movement of the plug is rendered almost impossible under ordinary circumstances, as it requires considerable force, even when the carrier-ring is in its proper position to force the plug forward.

Now, to close the breech, the carrier-ring and its plug are swung rather smartly into place, so that the carrier-ring may come to its proper bearing. The lever-handle is then raised till its axis is parallel with that of the piece, and the breech-plug pushed forward by means of the fixed bronze handle till its motion is arrested by the contact of the last thread on the breech block, which for this purpose is not cut away, with the thread on the base ring. Care should be taken to raise the lever-handle as indicated, otherwise the cam-head of the lever will come in contact with the face of the carrier-ring, and the breech-plug cannot be turned, as it is not pushed forward far enough to allow its threads to come opposite their spaces in the threads of the base-ring.

During this travel of the breech-plug the stops in the carrier ring slide in their grooves in the plug, the threaded sectors of the breech-plug move forward in the blank sectors of the base-ring, and the end of the latch-pin moves out of its recess up the incline, and along its groove to the point *a* (Fig. 2, Plate III), locking the carrier-ring again to the jacket. The plug in this position is shown in Fig. 1, Plate III, except that the lever-handle is raised, as above described.

The plug and carrier-ring being in this position, the plug is then turned to the right one-sixth of a turn, the lever-handle being kept raised.

During this movement the stops on the carrier-ring move in their transverse grooves till they come to a bearing at *dd* (Figs. 2 and 11, Plate III), when the motion of the breech-plug is arrested; the inner end of the latch pin moves down its transverse groove till it stops at *c* (Fig. 2, Plate III), thus unlocking the carrier-ring from the jacket. The lever-handle is now depressed, its head coming into the recess in the face of the carrier-ring, and its lower end fitting into its recess in the jacket.

The piece is now ready for firing, its breech mechanism being in the position first described.

The lever-handle is bent sideways to clear the vent.

THE FORGINGS.

These were received from the Midvale Works on the 27th of December, 1883. The tube was solid, the jacket, trunnion ring, sleeve, key-ring, and base-ring forged, bored, and turned roughly, and tempered in oil. The tube was not oil-tempered. The smaller forgings for the breech mechanism were received later.

Work on the plant was begun November 10, 1883, and on the gun itself January 8, 1884. The gun was finished and ready for shipment June 21, 1884.

THE PLANT.

Lathe for boring tube.—There was no lathe at the arsenal of sufficient length for boring and rifling the tube, and the first work done was to fit up one. Two shot-lathes were moved end to end, and their beds connected by straps, as shown at, *a*, *a'* (Plate IV). The lathes were also connected by a heavy bolt, and accurately leveled, making the beds practically continuous, and giving sufficient length between centers for all purposes. By moving head-stock and changing the counter-shaft this lathe was used for piercing the tube, then for reaming, and afterwards for rifling.

Boring tools.—(1) The tool used for piercing the tube is called a "hog-nosed tool" by the workmen. It is shown in detail in Plate V, Fig. 1, giving a plan, Fig. 2 a side elevation, and Fig. 3 a front elevation of the tool, and Figs. 4, 4*a*, 5, 5*a* the tool complete. It is made of steel, in two parts, the bar bearing the cutter-head being keyed together in the middle at *b*, *b* (Figs. 4*a* and 5*a*) with a taper key. A steel bar of proper size is upset to form the cutter-head *c* (Figs. 1 and 2). The bar and head are then turned to size, and one-half the cylinder is planed off at the head, forming the cutter-head, as shown at Fig. 3. Before this planing is done a hole *d* (Fig. 3) is drilled and tapped, and a screw-plug inserted, on which the center is accurately marked. The object of this is that the tool may be centered and its cutter accurately turned after it is screwed into place at *e e* (Figs. 1 and 2). When not in use this plug is removed, and its hole filled with waste, to keep out chips, &c. The shape of the cutter is shown at *e e e* (Figs 1, 2, and 3); its seat is accurately planed out in the cutter-head, and it is screwed into place and held by the two screw-bolts shown in plate; it is turned concentric with the head by the use of the screw-plug center already described; *f*, *f* is a small copper tube which runs along the tool, and is fastened to it with copper straps and screws. It supplies a stream of oil to the cutter during its progress through the tube. Its operation will be understood by a reference to Plate IV; it is there shown connected to a small hand-pump by a rubber tube. This pump stands in a vessel filled with lard oil, and by its action the oil is forced through the rubber and copper tubes, and issues in a stream against the cutter, and then runs back down the bore of the gun into the reservoir. This cutting-tool, being accurately turned, and entered properly in the bore, is self-centering, as is seen from its shape, and will guide itself and make a true hole. In the present case, after traveling a distance of nearly 8 feet, its divergence from a straight line was so slight that it could not be measured with any instrument on hand.

The form of its chips is shown in Figs. 6 and 6*a*, Plate V. As the chips are cut off they accumulate on the flat surface *c c* of the cutting-head, and the cutter must be drawn out and cleared when this space becomes filled. After a little experience the time is soon ascertained which it requires to fill up the cutter with chips, and no clogging need occur. It was found that a cut of about three-eighths of an inch was sufficient to fill up the cutter with chips.

Boring the tube.—The action of the tool is shown in Plate IV. The tube is represented at *b* (Figs. 1, 2, and 3, Plate IV). Four iron jaws are bolted to the face-plate of the lathe *c*, *c* (Figs 1 and 3). They are bored out to the diameter of the tube, a wrought-iron ring *d* (Figs. 1 and 3) shrunk over their outer ends to prevent springing, and screw-bolts passing through them, *e*, *e* (Fig 1), hold the tube in position for boring. A bearing is turned on the other end of the tube at *g*, and this end is supported by a back-rest.

The position of the piercing tool is shown at *k* (Figs 1 and 2), its first section only being represented. The second section is keyed on to the first as the boring progresses. The handle of the tool is held by two straps *m* (Figs. 1 and 3), the lower one being bent as shown in Fig. 3, and resting on the lathe-bed, along which it is free to move. By this lower strap the tool is held, and prevented from turning, as the tube rotates. The tool is fed forward by the hand-wheel of the tail-stock till it reaches the limit of its travel, when the tail-stock is moved forward and clamped, and the tool again fed forward from its new position. To draw the tool back for cleaning it of chips, &c., two straps are attached to the tail-stock center, shown at *n* (Fig. 1), and are connected longitudinally with the straps *m* by bolts and nuts *p p* (Fig. 1). The tube is driven by the head-stock of the lathe, and the cutter fed forward by hand and held as described, till the tube is bored to a depth equal to the length of the first section of the cutter-bar, when its second section, Fig. 5 and 5*a*, Plate V, is keyed on, and the boring completed. This was accomplished without any accident or delay, only one cutter being used in the operation. It was found that at a point about two feet from the muzzle the metal was soft for a distance of a few inches. This was shown by the movement of the cutter, which could be fed forward very rapidly at this point, while ordinarily its motion was very slow. The same thing was noticed at several other points, and would seem to indicate that the metal of the tube was not homogeneous. These spots afterwards showed very plainly in the rifling. No such defects were observed in the other parts of the gun, and as these were oil-tempered, while the tube was not, it is thought that it would be a great improvement if the tube after its first boring should be oil-tempered also. The time required for boring the tube was seven days of ten hours each, one man and a boy being required. It should be added that before using the piercing tool a hole was drilled to the depth of the cutter-head in the tube, and enlarged by the use of successive tools till it was the exact diameter of the cutter head, viz, 2.95 inches.

Tool for boring jacket and sleeve.—This is shown in Figs. 1 and 2, Plate VI. It is the ordinary boring bar used for boring cylinders. *a a* (Fig. 1) is the bar; it has a longitudinal groove in which rests the feed-screw *b*, turning in a collar at each end, and carrying a gear-wheel *c*, *c* (Figs. 1 and 2) at one extremity. The cutter is carried by a sliding-head *d* (Fig. 1) which fits the bar accurately and slides along it, driven by the feed-screw *b*, which passes through a fixed nut *d* on this sliding head. The cutter is shown at *e*. The manner of communicating motion to the feed-screw is shown in Fig. 2, and at *c* (Fig. 1). The boring-bar passes through the jacket, which is shown at *k*, *k* (Figs. 1 and 2), and is held firmly clamped at *m*, so that it turns with the head-stock of the lathe, while it rests at the other end against the lathe-center at *d′*. The jacket is held firmly and does not turn. Now, it will be seen by an inspection of the gears at *c* (Fig. 2) that when the boring-bar turns about its axis, the pinion *d′* being fixed, motion is communicated through the intermediate gearing to the feed-screw, which turns in its nut in the sliding-head at *d*, and the screw being fixed and its nut movable, the nut with the sliding head attached moves forward slowly parallel to the axis of the bar, and is at the same time, by the motion of the bar itself, carried round in a circle, so the cutter makes a spiral cut on the interior of the jacket.

Boring the jacket.—The interior of the jacket was first bored out to its smaller diameter, and then by means of suitably shaped cutters, shown in 1, 2, 3, 4, 5, 6 7, 8, 9 (Plate VI), the larger diameter was bored, and by stopping the feed at the shoulder and causing the tool to move in a circle, the proper shape was given to the shoulder. The outside of the jacket was then turned to a cylinder, its diameter being a little greater than the maximum finished diameter, and the shoulder turned on front end of jacket. The time required for this work was nineteen and one-half days of eight hours each, one man being employed. The same bar was used for the sleeve. Time required for boring and turning sleeve six days of eight hours each, one man being employed. The sleeve was rough-turned only, on the outside, except for a distance of about 1 inch, at the end next the trunnion ring, where it was turned down accurately to finished dimensions for shrinking.

Wood reamers for tube.—After the tube is pierced with the first cutter previously described, to a diameter of 2.95 inches, it is finish bored up to its diameter of 3.2 inches with wood reamers. Three different sizes of these were used, two for the intermediate cuts, and one for the finishing or polishing. These reamers are similar in construction, and vary only in diameter, according to the cut they have to make. Their construction and cutters are shown in Figs. 5, *5a*, *5b*, 6, 3, and 4, Plate VI. *a a′* (Figs. 3 and 4) is a flat steel forging, terminating at *a′* in a frustum of a cone having a slot through which a key passes to join it to its boring bar. A front view is given in Fig. 6. Two bolt holes are drilled through the flat part of the reamer *b* (Fig. 4), and through these pass the bolts which hold the two pieces of wood *c*, *c* in position On the sides of the forging at *d* two dovetailed slots are planed out, and into these the two cutters are driven tightly. The shape of the cutters is shown in Figs. 5, *5a*, *5b*. The wood is generally cherry, thoroughly saturated with oil, and after being bolted into place and the cutters driven in, the reamer is centered in a lathe, and cutters and wood turned accurately to the size of the cut to be made. The wood fits the bore very tightly and forms a bearing for the reamer, the steel forging not coming in contact with the metal. A groove is made in the wood, in which lies the copper tube, which runs along the cutter bar, and furnishes a stream of oil to the cutters, as explained in using the piercing tool. This groove is shown at *e* (Figs. 4 and 6, Plate VI).

The boring and rifling machine—Plate VII shows three different views of the rifling machine which, with a few modifications, was used for boring with the wood reamers. This machine, in all its details, was the original design of Mr. H. P. Elwell, draughtsman at this arsenal, and has worked perfectly, without any hitch or trouble of any kind. The machine was built from his drawings without any changes or modifications, and none have been found necessary, and it seems to be all that could be desired for the purpose.

For boring, the machine is arranged as follows: In Fig. 1, Plate VII, *a*, *a* are the ways of the lathe previously described (the two shot lathes joined together), *b*, *b* (Figs. 1 and 2) the headstock, *c*, *c*, *c*, a friction clutch with its pulleys. In the boring machine this clutch and its pulleys are not used, being replaced by the ordinary speed cone; *d*, *d* is the boring bar, or bar which carries the wood reamers. It is a hollow pipe, 2¼ inches outside diameter and 1½ inches inside, length 117 inches. At the front end, at *e* (Figs. 1 and 2), a slot is cut through the bar, and through this passes a key which, fitting into the corresponding slot in the wood reamer, keys the latter into its place on the bar, as shown in Fig 2. The inside of the bar at *e* has a taper corresponding with that on the wood reamer. *f* (Figs. 1 and 2) is the tailstock of the lathe with the spindle and hand-wheel removed, and a casting *f′ f′* substituted for it, containing a bearing, *f′*, for the front part of the boring bar. A key-way is cut along the boring bar its whole length, and a key inserted in the bottom of the front bearing. This prevents the boring bar from turning during its forward motion.

This front bearing is fixed as near the muzzle of the gun as possible, and held firmly by bolts.

g, *g* (Figs. 1 and 2) is called the "sliding head." It is made of cast iron, and its general shape is sufficiently indicated in the drawing. It slides freely along the ways of the lathe. *h*, *h* (Figs. 1 and 2), on the front part of the sliding head, forms the rear bearing for the boring bar. On the rear end of the boring bar an iron collar is shrunk, whose length is sufficient to fill the space *k*, *k*, between the front bearing *h*, and the rear bearing *h'*, of the sliding head. In this rear bearing *h'* of the sliding head rests a bronze nut, *m*, with a pitch of one-tenth of an inch. The front face of this nut rests against the rear face of the collar on the end of the boring bar, but otherwise they are not connected, except through the sliding head. *n* is the boring-bar screw, or feed-screw. This screw has a pitch of one-tenth of an inch, a diameter of 1⅜ inches, and a length of 117⅛ inches. It is tapered at the end next the headstock *b*, and fits into the corresponding tapering socket in the lathe spindle, where it is secured by a pin, and from this lathe spindle it receives its motion. It then rests on the bearing at *o*, which is simply a sliding rest, following the motion of the sliding-head *g*, and serving to steady the screw. The sliding rest and sliding head are connected by the bolt *p* (Fig. 2). The bed screw *n* then passes into the bronze nut *m*, and thence into the interior of the boring bar *d*.

Action of the machine in boring.—From the description of the various parts, their action is evident. The gun being secured in the lathe, in the position shown in Plate IV, Fig. 1, and the reamer keyed to its bar at *e* (Plate VII), the gun is made to revolve, motion being communicated to the cone and face plate to which it is bolted. Then the speed cone at *c*, *c*, *c* is set in motion. The feed screw *n* being secured to the spindle of this cone, revolves with it, and being fixed, while its bronze nut *m* is movable, this nut is driven forward. This nut bears against the collar on the rear end of boring bar, and hence the boring bar and the sliding head *g* are driven forward. The boring bar slides through its front bearing at *f'*, and is prevented from turning by the key, which slides in the key-way along the bar. The cutter is therefore carried forward, and travels down the bore while the gun revolves. After the sliding head *g* has moved forward the length of the bolt *p* (Fig. 2), the nut on the end of the bolt comes to a bearing against the front surface of the sliding head, and the sliding rest *o* is then pulled along at this distance from the sliding head, supporting the feed-screw and preventing vibrations. A constant stream of oil must be kept flowing against the cutter through the tube, as previously explained.

Boring the tube.—Two cuts were made with the reamers before shrinking, leaving only the finishing cut to be made after that operation. The object was to remove all the metal possible before shrinkage, so that no change should take place from cutting away after that operation. The first cut was 0.055 inch in depth, increasing the diameter of the tube from 2.95 to 3 06 inches. The time required to make the cut was about ten hours. After the first cut had progressed about 5 feet, the rubber tube supplying the oil burst, and the cutter broke, and also part of the forging of the reamer, owing to lack of oil. This, however, was soon remedied, and caused no damage to the tube. No further trouble of any kind was experienced in the boring. The second cut was .045 inch in depth, increasing the diameter of the tube from 3.06 to 3.15 inches, and required about the same time. This left .05 inch to be removed in finishing, and this was done in two cuts after the shrinking, the first cut taking nearly all the metal, and the second being only a polishing cut and very slight.

The rifling machine.—Many of the parts already described as belonging to the boring machine are common also to the rifling machine. It is shown in Plate VII. In rifling the gun it is necessary to give a motion of rotation to the rifling tool, as well as of translation, the gun being held firmly, and this motion of rotation must of course correspond with the twist of the rifling; in the present instance, one turn in eight feet. The modifications in and additions to the boring machine, are then principally for the purpose of obtaining this rifle motion. In general this arrangement is simply a modification of the screw-cutting gears which are found on almost every lathe. The rifling bar, which carries the rifling tool, is shown at *d*, *d* (Figs. 1 and 2). It differs in dimensions from the boring bar, its outside diameter being 2¾ inches, inside 1½ inches, length 104 inches. The pipe being thin a wrought-iron plug is welded into the front end, and bored out tapering to fit the corresponding taper on the rifling head. The rifling bar fits in a front bearing at *b′*, through which it slides. Figs. 1 and 2, Plate VIII, show the rear end of the rifling bar. This bar rests in its bearing in the sliding head *h* (Fig. 1, Plate VII), at *h*, *h* (Fig. 2, Plate VIII). *b*, *b* (Figs. 1 and 2, Plate VIII), is a wrought-iron collar, shrunk on the rear end of rifling bar; *a*, *a* is one of the gears on the rifling bar, shown also in Figs. 1 and 2, Plate VII. *c*, *c* (Figs. 1 and 2, Plate VIII, and 1 and 2, Plate VII), is a cast-iron disk, fitted to the wrought-iron collar, on rifling bar, as shown in Fig. 2, Plate VIII, and held securely to it by the four screws *d*, *d*, *d*, *d* (Figs 1 and 2, Plate VIII). It has also 24 taper holes, corresponding to the number of grooves in the gun *k*, *k* Fig. 1, Plate VIII. Through the gear-wheel *a* a hole is drilled (shown at *e*, Fig. 2, Plate VIII), and tapped, and in this hole is inserted the steel bushing, Fig. 4. The outer end of this bushing is tapped, and the screw-thread cut away, Figs. 4 and 4*a*, forming an interrupted screw-thread, and in this thread and projecting through the hole, and into each of the holes of the cast-iron disk in succession, works a taper steel pin, Figs. 3 and 3*a*, with an interrupted thread corresponding to that in the bushing. The gear-wheel *a*, *a* turns freely on the rifling bar, and communicates no motion to the latter, so long as it is not connected with the cast-iron disk. This disk, it will be seen, is firmly connected with the rifling bar by means of the four screws *d*, *d*, through the wrought-iron collar, and hence it communicates any motion of rotation it may receive to the bar. Now, when the tapering steel pin is inserted through its bushing in the gear *a* and into one of the holes of the disk *c*, and locked there by means of its screw thread, the gear and cast-iron disk become locked together firmly, and any motion of the gear will be communicated to the disk and rifling bar, and they will all revolve together. The use of the interrupted thread is obvious. By giving the pin one-fourth of a turn, the threads become unlocked, and the pin may be drawn out, the disk and its rifling bar and cutter revolved one twenty-fourth of a turn, till the cutter comes opposite the next groove in the gun, when the pin is replaced, the disk and gear locked together, and the machine ready to start on a new cut.

This gear *a*, with its disk and collar, rests in the space between the two bearings of the sliding head, as shown in Figs. 1 and 2, Plate VII, the front face of the gear bearing against the rear face of the front bearing, *h*. In the rear bearing *h* of the sliding head in the bronze rifling nut *m* through which passes the driving-screw *n*. This nut has a pitch of 1 inch for its thread. Its front surface bears against the rear face *b*, *b*, of the wrought-iron collar on the end of the rifling bar, Figs 1 and 2, Plate VII. The driving-screw then rests in the sliding bearing *o* (Figs.

1 and 2, Plate VIII), which follows the sliding head and supports the feed-screw, as explained in the case of the boring machine. The end of the screw, next the headstock tapers, and fits a corresponding tapering socket in the lathe spindle, to which it is secured by a pin. Hence, when motion is communicated to the lathe spindle the screw turns with it. The screw and its nut are left handed; *c′*, *c′*, *c′* (Figs 1 and 2, Plate VII), is a friction clutch, which is very quick in its action, and by which direct and reverse motion can be obtained. The clutch is worked by an arrangement of shipping rods and levers, shown in Fig. 2, Plate VII, at *r*, *r*. This is so arranged that the workman may stand at the muzzle of the gun, and work the clutch with the handle *r′*. It is generally, however, worked automatically, by two stops *r″*, *r‴* (Fig. 2), fastened to the rod *r*, and a corresponding projecting strap *s* bolted to the front of the sliding head. When the sliding head carrying the cutter reaches the end of its travel, the strap *s* strikes against the front stop *r″*, shifts the clutch, and stops the motion of the cutter. On its return down the bore, when the cutter has cleared the bore, and reached its proper position, this strap *s* strikes the stop *r‴*, and again stops the motion of the cutter.

On the outside of the lathe spindle at *t*, *t* (Figs. 1 and 2, Plate VII) is keyed a small pinion. It receives its motion from this spindle, turns with it, and transmits this motion, modified and reduced by means of the intermediate gearing shown in the figure, to a gear on the spline shaft. The general arrangement of this gearing is shown in Fig 3, Plate VII. It is held by a frame bolted on to the headstock, and a detailed description is unnecessary. This spline shaft is shown at *m*, *m* (Fig. 1). It rests in two bearings, one bolted to the tail stock at *n*, and the other to the headstock at *n′* (Fig 1). A key-way is cut along the shaft. This shaft passes through bearings at *s* on the sliding head, and carries a pinion at *t*, which gears into the wheel *a*. As this sliding head moves, carrying with it the gear *a*, the pinion also slides along its shaft *m*, *m*. The other gear wheel on the spline shaft is shown at *p* (Fig. 1). The motion which is communicated from the pinion on the lathe spindle is carried to this gear-wheel *p*, which causes the spline shaft to rotate; this motion is transmitted by the pinion *t*, to the gear-wheel *a*, and consequently to the rifling bar. A table of the gear is given in drawing Plate VII, and by changing one gear (that marked 60 *teeth*) for another of the proper number of teeth, any uniform twist can be obtained. The bar makes one turn to ninety-six turns of the spindle, the velocity ratio being one to nintey-six, and giving the required twist of one turn in 96 inches.

The rifling tool.—This is shown keyed into the rifling bar in Fig. 2, Plate VII, and its details are shown in Plate IX, with a section Plate VIII, Fig. 5. It was designed by Mr. H. P. Elwell, also, and made from drawings furnished by him, and has worked perfectly. A general view of the tool is given in Fig. 1, Plate IX. The head *a* is a solid forging of low steel, ending in a taper *b*, corresponding to that in the front end of rifling bar, and having a slot *b′* for the key by which it is fastened to the bar. On the exterior the slots *c*, *c* are planed out, and pieces of bronze dovetailed into them, forming bearings which rest against the bore, and prevent the contact of the steel head. Fig. 2, Plate IX, gives a front view of the rifling head, with its bronze bearings. On the interior the head is broached out to the point *a* (Fig. 5, Plate VIII), of such a shape as to receive a sliding pin, shown at *b* (Fig. 5, Plate VIII), and in section at *a* (Fig. 3, Plate IX). From this point *a* (Fig. 5, Plate VIII) to the bottom *d* (Fig. 1, Plate IX), the hole is cylindrical in shape, and forms a bearing for the end *b′* (Fig. 5, Plate VIII) of this pin, which slides in it. The front bearing of this pin is shown in section (Fig. 5, Plate VIII). It has first a screw-thread cut on it, *c*, and on this is screwed a long nut, *d*. This nut is of steel, and sliding in a bronze bearing, *e*, forms the outer bearing of the pin. This bronze bearing is screwed to the front of the rifling head with the screws *e*, *e* (Fig. 2, Plate IX). On each side of this sliding pin is an inclined groove, shown at *f* (Fig. 5, Plate VIII). Across the face of the steel rifling head is planed a dovetailed slot, *d*, *d* (Fig. 2, Plate IX), and in this slot fits a sliding piece (Fig. 3, Plate IX). In the middle of this sliding piece is a hole, *a* (Fig. 3, Plate IX), of the exact shape of the sliding pin, and through this hole the pin passes. Two little projections, *b*, *b*, fit into the inclined grooves on the sides of the sliding pin. At the upper end of this sliding piece is a socket, *c*, with a threaded hole. The cutter is fixed in this socket with a screw. The cutter is shown in Figs. 4 and 4*a*, and in position at *k* (Fig. 2, Plate IX). All the parts are made of steel, except the bronze bearings *c*, *c*, for the rifling head, and the bearing for the sliding pin *e*, *e* (Figs. 1 and 2, Plate IX). An inclined hole, *m* (Fig. 2, Plate IX), through a lug on the front part of the bronze bearing *e e*, admits the passage of the copper tube supplying oil to the cutter.

Action of the rifling tool.—The rifling head being keyed in position in its bar, as shown in Fig. 2, Plate VII, and the cutter *k* (Fig. 2, Plate IX) being fastened in its socket by the screw *n*, the nut *d* (Fig. 5, Plate VIII) is drawn forward till its head at *g* (same figure) rests against the shoulder of the front bearing *e*. By this motion the pin *b*, *b′* is also drawn forward, and the lugs *b b* (Fig. 3, Plate IX), of the sliding piece, move in the grooves in the sides of the pin, and cause this sliding piece and its cutter to rise into the position shown in Fig. 2, Plate IX. If the cutter does not project enough, it is raised by turning the nut *d* (Fig. 5, Plate VIII), by which movement of the nut the sliding pin is allowed to move farther forward, and consequently the sliding piece and its cutter are raised higher. In this manner the cutter may be set for a cut of any depth. This being done, the cutter is driven forward along the groove in the gun, the forward nut *d* resting with its shoulder *g* (Fig. 5, Plate VIII) against the corresponding shoulder on the front bearing *e* till it reaches the end of its cut at the bottom of the bore. When it reaches this point the forward end *m* of the sliding pin (Fig. 5, Plate IX), strikes against a projecting pipe, working on a spring, which is inserted in the axis of the tube at the rear, and the sliding pin is pushed back in its bearings, carrying its nut *d* along with it (this nut sliding freely in its bearing *e*), until the shoulder on the pin comes against the shoulder *a* (Fig. 5) in its recess. By this motion the sliding piece *n* (Fig. 5), with its cutter, is drawn in, moving at right angles to the motion of the pin. The motion of the rifling machine is then reversed, and the rifling bar and cutter withdrawn. When the cutter is drawn out of the bore the sliding pin is pushed forward by hand till its nut again rests in position against the shoulder *g*, when the cutter is again in position to move forward.

Action of the rifling machine.—Referring to Plate VII, Fig. 2, suppose the rifling bar and cutter to be in the position there indicated; at *x*, *x* is shown a small copper tube passing through the inclined hole in the front bronze bearing of the rifling head. This tube is flattened at its front end into the shape of the orifice of a gas burner, and projects near the cutter. To the other end is attached a rubber tube, and through this tube a constant supply of oil is forced with the the hand-pump before discribed. This oil issues from the tube, and against the cutter, in a thin flat stream. The rubber tube is fed in at the rear of the gun, and is pushed before the cutter as it travels down the bore, and pulled after it as the cutter is withdrawn.

The workman, standing at the cutter, starts the rifling machine, using the handle *r'* (Fig. 2, Plate VII.) Motion being communicated to the screw, it turns in its nut, driving the sliding head forward, and carrying with it the rifling bar and its cutter. At the same time the motion is transmitted to the spline shaft by the gearing, as before explained, and the pinion *t* (Fig. 1), sliding on its shaft and gearing into *a*, gives the proper rotary motion to rifling bar and cutter. At the end of the cut the pin in the rifling head strikes the projecting pipe and the cutter is drawn back, and at the same instant the strap *s* on the sliding head strikes the stop *r''* on the shipping rod *r*, the clutch is thrown off, and the forward movement of the rifling head stops. The workman then throws the clutch into action on the opposite pully, the motion is reversed, and the screw revolves in the opposite direction, drawing out the cutter. When the cutter has reached its proper position and cleared the bore, the stop on the sliding head strikes the stop *r'''* on the shipping rod, throws out the clutch, and stops the motion of the rifling head. The pin *e* (Fig. 2, Plate VIII), which unites the cast-iron disk *c* and the gear *a*, is then withdrawn; the disk, and with it the rifling bar and cutter, revolved one twenty-fourth of a turn till the next one of the holes *k*, *k* (Fig. 1, Plate VIII) comes opposite the hole *e* in the gear, when the pin is again inserted and locked. During this movement of the rifling bar and disk the gear *a* will not turn, as it is held by its connection with the other gears. This movement of the cutter brings it opposite the next groove in the gun. The sliding pin in the rifling head is then pushed forward, which raises the cutter to its proper position, and then the machine is ready for starting again.

This is continued till the cutter has traveled down the 24 groves, taking a chip of the same thickness from each. The cutter is then set out by its nut *d* (Fig. 5, Plate VIII) for a new cut in each of the 24 groves, as explained. The cutter travels about 6 feet per minute, measured along the axis of the tube. Time required to rifle gun five days of eight hours each, one man and a boy being employed. The depth of the grooves was 0.05 inch.

Tools for boring powder chamber, and turning outside of jacket.—The shapes of the powder chamber and jacket have already been shown, the former being a frustum of an ellipsoid, and the latter a figure closely resembling it. For boring the powder chamber the apparatus shown in Plate X was used. *a* (Figs. 1 and 2) represents the tube, *b* a casting accurately bored out to fit the bar *c*. This casting is bolted to the tool-post of the lathe, as shown, and is cut open longitudinally at the top, and held together or tightened with two screw-bolts, *d d*. On loosening these bolts the bar *c* can be drawn out of the holder, or moved to any position, and clamped firmly by screwing up the bolts. An end view is given in Fig. 5. The bar is simply a round steel bar, with a slot, *e*, at the forward end, carrying a cutting tool. Two cast-iron pieces, *g*, *g* (Fig. 1), are laid across the ways of the lathe and bolted securely in position. On these, and bolted to them, is a piece of cast-iron, *h*, *h*, passing over the top of the lathe-slide, and so arranged that the slide may travel freely along the ways and clear it. At *k* is a steel former, of the exact shape and dimensions of the powder chamber, screwed to the cast-iron piece *h h*.

In Figs 3 and 4 is shown an arrangement which is bolted to the side of the tool-post at *m*. This arrangement consists of a piece, *a*, *a* (Figs. 3 and 4), shaped as represented, and having at *b* an oblong hole. In this hole is a cylindrical pin of steel, *c* (Fig. 4), terminating underneath in a knife-edge, which bears against the steel former *k* and travels along it, and above in a screw-thread, to which a nut is fitted. Under this nut, and passing over the pin is a lug, *d*, to which a wire rope, *a* (Fig. 5), is attached. Through one side of the oblong hole a set screw works, *e* (Fig. 4). This set screw rests against the cylindrical steel pin, and moves the cutter and its bar forward, when the nut *m* is slightly slackened. *b* (Fig. 5) is a small casting bolted to the lathe-slide and carrying a small pulley, over which the wire rope *a* passes. A weight, *d*, is attached to the other end of this rope.

Action of the apparatus.—The tool being arranged as shown in Figs. 1 and 2, and the transverse feed-screw of the lathe removed, the tube is made to revolve in its bearings, and the lathe-slide, driven by the lead screw, moves forward. The tool-post of the lathe being free to slide transversely, the weight *d*, attached to the wire rope *a* (Fig. 5), acts on the lug to which the rope is attached at its other end, and keeps the steel knife-edge *c* (Fig. 4) constantly pressed against the former *k* (Fig. 1). The tool *e* being rigidly connected with this knife-edge, as before shown, is forced to describe a curve of the same shape as the former. After a cut is made and the tool withdrawn the cutter is fed forward by slightly slacking the nut *m* (Fig. 4) and turning the set screw *b* (Fig. 3), which acts against the steel pin *c* (Fig. 4), and moves the bar and its cutter out.

This same arrangement was used for turning the outside of the jacket, a former of the proper shape being used, and a tool in an ordinary tool rest being substituted for the bar *c*. It was found in boring the powder chamber, when making the first cuts, that there was some vibration of the bar and cutter, owing to the distance of the cutter from its holder, but in the finishing cuts no trouble was experienced from this source.

Operations preceding shrinking.—All the plant above described, together with the apparatus used in shrinking, and to be described further on, was completed before shrinking, and the work done on the gun was as follows: The tube was pierced with the hog nosed tool, and bored up to a diameter of 3.15, making two cuts with the wood reamers; the powder chamber was rough-bored, leaving a finishing-cut only to be taken after shrinkage; the tube on the outside was turned down to dimensions for the reception of the jacket, trunnion-ring, and sleeve; the screw-thread was cut for the key-ring; from the end of the key-ring to the muzzle, the tube was rough-turned, leaving as much metal as possible to insure stiffness in the subsequent turning. The jacket was finished inside to dimensions and the shoulder turned on its forward end; on the outside the jacket was left cylindrical in shape, and of a diameter a little greater than its maximum exterior diameter when finished. The object of this was to leave the metal as uniform in thickness as possible, so that when heated for shrinking unequal expansions and contractions would be avoided. It was also hoped that, by having this uniform thickness of metal, the chances of cooling before the tube was in place would be lessened.

The trunnion-ring was finished to dimensions throughout before shrinkage, except the corners of the metal, which could not be reached with the lathe or planer. These were chipped and filed after shrinkage.*

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* Time required to finish trunnion-ring twenty days of eight hours each, one man being employed.

The sleeve was finished inside to dimensions. On the outside, as before stated, it was turned to dimensions only for about 1 inch from the front of trunnion-ring. The remaining portion of the exterior was rough-turned to a uniform diameter. The key ring was finished on the interior, and its screw thread cut, and rough turned on the outside. After the parts were finished and ready for shrinking they were carefully measured. The measurements are given in table No. 1.

In making the exterior measurements and in turning the parts of the tube snap gauges were used, which were carefully set by means of pointed steel wires. These wires were first accurately measured with the vernier calipers, a rubber tube being drawn over them (the wires) to prevent expansion by the heat of the hand. For interior measurements steel wires were used, made and protected in the same way. For making interior measurements, where the diameters varied slightly, a piece of hard wood was used. Two wood-screws were inserted in this, one at each end, and their heads filed off and pointed. This wood, with its screws, was inserted in the bore of jacket, &c., and the screws gradually turned out till contact was made between the points of the screws and the metal, one of the screws being held in a fixed position and the other moved by the hand first in a plane perpendicular to the axis of the bore and then at right angles to this plane till contact was made. The resulting length was then read off on the vernier calipers. The prescribed shrinkage was .0015 inch per inch of diameter. To give the prescribed shrinkage the jacket trunnion-ring and sleeve were bored accurately to dimensions, and the corresponding parts of the tube were turned to this diameter plus the shrinkage. For instance, the diameter of the interior of the jacket, from the rear end to the shoulder on the tube, was 6 inches. The diameter of the corresponding portion of the tube was $6.0 + 6.0 \times .0015 = 6.009$ inches, and in a similar manner the other dimensions for the exterior of the tube were obtained.

Form of shoulder on trunnion-ring and jacket.—Plate XI, Fig. 5, shows the form of this shoulder as originally designed, and Fig. 5 *a* shows the form of shoulder as finally adopted and used. The first form (Fig. 5) was abandoned on account of the mechanical difficulty of making a tight joint in shrinking. The second form, a straight taper, was suggested by the commanding officer and approved by the Ordnance Board. The depth of the shoulder was not given in the drawing, as no tests had been made of the metal. In order to determine this depth of shoulder, or the difference between the radii x' and y (Fig. 5*a*, Plate XI), at the front and rear of the shoulder, a specimen was taken from the metal of the jacket, and this was used because there was no specimen from the trunnion-ring available. As will be seen, the radius y of the front of the shoulder is greater than x', the radius of the rear part. The jacket is first shrunk on and then the trunnion-ring, and in this operation it is necessary for the part of the trunnion-ring whose radius is x, and which is smaller than y, to slip over y. The trunnion-ring being heated for this purpose, when it has expanded to its proper dimensions for shrinking on the tube the part of the shoulder whose radius is x must also have expanded sufficiently to slip over y, and without applying sufficient heat to cause a permanent set in the metal. It was found as a result of tests in the testing machine that the metal of the trunnion-ring extended more at its elastic limit than that of the jacket, and it was thought that any results of heating obtained for the metal of the jacket would be true also for that of the trunnion-ring. Nothing was known about the action of the metal under heat, and it was therefore the object to decide the following points:

1. The expansion of the metal per unit of length (which is the same as that per unit of circumference) at different temperatures.

2. The degree of heat required to produce a permanent set in the metal on cooling.

The specimen of the jacket before mentioned was a small rectangular prism, whose dimensions were: length, 3.468 inches; height, 1 inch; width, .5 inch.

It was accurately measured after each heat with the vernier calipers.

1. It was first heated to a strong black heat and its length measured, and found to be 3.496 inches. The total expansion at this temperature was then 3.496 − 3.468 = .028. It was then cooled down and measured, and found to be 3.468 inches, its original length. Hence, there was no permanent set at this temperature.

2. It was then heated to a blood-red heat and measured, length, 3.502 inches; total expansion at this temperature, 3.502 − 3.468 = .034 inch. It was then cooled down and measured, and found to have returned to its original length. Hence, there was no permanent set at this temperature.

3. It was then heated to a cherry red and cooled, and its length when cold was 3.479. Hence, its permanent set at this temperature was 3.479 − 3.468 = .011 inch.

These experiments are not claimed to be accurate, as there was no means of determining the exact temperature, but they gave an indication of the behavior of the metal under heat, and showed to what point it could be heated without injury in the shrinking.

As the black heat was the one intended to be used, its results were taken as a basis in calculating the shoulder. The expansion per unit of length at a black heat is $\frac{.028}{3.468} = .00807$ inch. Now, if we suppose the two surfaces of contact to be cylinders, and that this surface of contact is midway between the inner and outer surfaces of the jacket at the forward end, we shall have the diameter of this surface of contact equal to the exterior diameter of the tube at this point plus one half the thickness of the metal of the jacket or equal to 5.6 + .95 = 6.55 inches. Under this supposition, if the metal of the trunnion-ring be expanded at a black heat, this diameter will become 6.55 + 6.55 × .00807 = 6.6028 inches, and the total expansion will be 6.6028 − 6.55 = .0528 inches, or for the radius $\frac{.0528}{2} = .0264$ inches. That is, the trunnion-ring being so expanded will just pass over a ring whose diameter is 6.6028 inches. This will then be the difference of radii between the forward and rear ends of the shoulder, neglecting shrinkage, and the shoulder will taper from front to rear (from y to x' on the jacket) .0264 inch in a distance of 1.25 inches. Now before expansion the radius of the part x on the trunnion-ring is $\frac{6.55}{2} = 3.275$. After expansion at a black heat it becomes 3.275 + .0264 = 3.3014 inches, and when thus expanded it must pass over the part y on the jacket. Hence y must have a radius of 3.3014 inches. The radius of x is 3.275 inches.

This does not allow for any shrinkage between the surfaces of contact, as in cooling the parts come back to their original size, and x and x' would have the same radius, and also y and y'. To give the proper shrinkage, since x and y are fixed by the conditions given, the shrinkage must be obtained by *increasing* x' and decreasing y' the proper amount.

The radius of x is 3.275 inches, the shrinkage is .0015 inch per inch of diameter; hence, 3.275 + 3.275 × .0015 = 3.2799 inches for the radius x'.

The radius of *y* is 3.3014 inches; hence, 3.3014 − 3.3014 × .0015 = 3.296448 inches for the radius *y′*.

Hence the depth of the shoulder will be on trunnion-ring—

$$\begin{array}{rl} \text{Rad } y' = & 3.296448 \\ \text{Rad } x = & \underline{3.275} \\ & 0.021448 \text{ shoulder} \end{array}$$

On jacket—

$$\begin{array}{rl} \text{Rad } y = & 3.3014 \\ \text{Rad } x' = & \underline{3.2799} \\ & 0.0215 \text{ shoulder} \end{array}$$

A depth of .02 inch was adopted for each shoulder, and when shrunk together no difficulty was experienced, and a perfect joint was formed as far as could be observed. The joint between the forward end of trunnion-ring and the sleeve was without any hook or shoulder, the ends abutting against each other and making a square joint.

APPARATUS USED IN SHRINKING THE PARTS TOGETHER.

The different parts of this apparatus are shown in Plate XII. Fig. 1 is a casting shown in cross-section in 1 *a*. It rests on two T-rails, shown at *a a*. It is bored out at *b* for the tube to drop through. *c c* are lugs, which are bored out concentric with the hole *b*, and of a diameter equal to that of the exterior of the jacket. A cast-iron ring (Figs. 2 and 2A) fits against the surface *s s* (Figs. 1 and 1*a*), and on it the jacket rests, shoulder down, when heated for shrinking. Plate XIII shows the jacket in the position described. *d d* (Fig. 1, Plate XII) are holes in the lugs of the casting, through which pass the jointed bolts, one of which is shown in Fig. 4. Figs. 3 and 3*a* is a casting which rests on the rear end of the tube when it is swung into position for dropping through jacket, trunnion-ring, and sleeve. *d d* are holes for the screw-bolts, shown in Fig. 4; *b* is bored out for the reception of a cast-iron plug, shown in Plate XIII at *a*. This cast-iron plug enters the hole *b* sufficiently to be centered, and at the other end it enters the tube for a short distance. The exterior diameter of this plug is such that it will enter freely the rear of the jacket and force the tube into place against the shoulder on the jacket. This position is shown at *a* (Plate XIV). The interior of the plug is hollow, to allow the passage of the wrought-iron rod *b* (Plate XIII). Fig. 4, Plate XII, is a jointed bolt of wrought iron, two of them being used in the shrinking. The upper joint has a screw thread cut on it, and a nut resting against the upper surface of the holes *d d* in the casting Figs. 3 and 3*a*. The two sections of the bolt are joined together with heavy iron pins at *a*, Fig. 4, which can be readily removed, and the rods disconnected at this point. Figs. 5 and 5*a* are two channel bars, each having two holes, through which the bolts, Fig. 4, pass. The position of these bars is shown at *c*, Plate XIII. *d*, Plate XIII, is a fire pot made of boiler iron, in two sections, so that the top can be removed and the height decreased for the trunnion ring and sleeve. Fig. 6, Plate XII, is a gas collar, used for keeping up the heat after the fire is removed, and Fig. 7 a water collar used for cooling the parts after they are in place. These arrangements were suggested by Mr. John Allen, the workman in charge, and the jointed screw-bolts, which made a tight joint possible, by Mr. H. P. Elwell.

Shrinking the parts.—The parts having been finished, as before described, and accurately measured, and the tube star-gauged, the parts were next shrunk together. This was done in the arsenal foundry, as there was a shrinking pit there and other conveniences. The chassis of a 10-inch carriage was stripped of its traverse, wheels, &c., and placed across the top of the pit, as shown in Plate XIII at *e e*. Across this at right angles were laid the T-rails *g g*, which were held together by two cross-bolts. On these T-rails was laid the casting, as shown in Figs. 1 and 1A, Plate XII. Under the T-rails were placed the channel-bars *c c*, Plate XIII, and through the holes in these and the holes in the lugs of the casting, Fig. 1, Plate XII, passed the lower section of the bolts shown at *k k*, Plate XIII. These bolts rested on the shoulders *b* (Fig. 4, Plate XII). which bore against the upper faces of the casting, and were held underneath by their nuts *c c* (Plate XIII). These channel-bars were used, as it was feared the heat might crack the large casting, Fig. 1, Plate XII. Resting on the T-rails is the fire-pot *d* (Plate XIII). A temporary grate was made by laying iron bars across the rails. The jacket was placed in the position shown in Plate XIII, shoulder down, and the wood (dry pine) piled around it and placed inside the bore.

A long wrought-iron rod was passed through the tube, as shown in Plate XIII, having a hook at the rear end. This rod passed through an iron washer and a wooden plug at the muzzle and through a wooden plug at the breech. The cast-iron plug *a* was them inserted in the breech, and at the other end into its recess in the cross-head *x*. The threaded sections of the screw-bolts were put in place as shown.

The tube was swung by a traveling crane with a stop, so arranged that the tube could be brought vertically over its jacket, and when the latter was sufficiently expanded by heat the tube could be lowered rapidly through the jacket into its place. The length of the screw-bolts was so arranged that, when the tube dropped into its place, the jaws *l l* would be in the proper position for the insertion of the heavy pin joining them together. It will be seen from the plate that the lower sections of the bolts are in the fire-pot and surrounded by the fuel, and they, of course, expand as they become heated.

When the jacket or other part has been expanded sufficiently, the fire-pot is lifted by its handles and thrown off, the fire knocked away, and the interior of the jacket, &c., brushed out quickly, to clear away any ashes or dirt that may have accumulated. The tube is then swung round into position and lowered quickly, the plug *a* entering the interior of the jacket, and the tube coming up to its shoulder under the action of its own weight and that of the cross-head and screw-bolts. The jaws of the screw-bolts then come into their proper positions, and the pins are inserted, holding the sections together. In shrinking on the jacket these screw-bolts were not required, as the weight of the tube and cross-head was sufficient to bring the tube up to a shoulder. A mark was made on the tube .05 inch in front of the forward end of the jacket when in place, and it was found by measuring from this mark after shrinkage that the shoulders on the tube and jacket were in their exact position.

The position of the jacket and tube before shrinking is shown in Plate XIII. The jacket having been expanded .01 inch beyond the corresponding dimensions of the tube, the fire-pot *d* is removed, as explained, the fire knocked away, the jacket cleaned out, and the tube, having been swung round into the position shown, is lowered quickly into place. The water collar having been previously slipped over the jacket, the latter is allowed to cool gradually, and finally the water is turned on. The time required to heat the jacket to the proper degree of expansion was one hour and two minutes. Measuring screws attached to a wood handle, as previously described, were used in ascertaining when the proper degree of expansion was reached. A black heat was found to be sufficient.

After the jacket was shrunk in place, the tube and jacket were hoisted up and the trunnion-ring placed in position in the fire-pot, as shown in Plate XIV. The top section of the fire-pot was removed, and the fire kindled. Time required to heat up trunnion-ring was forty-five minutes. The measurements were made as before. When sufficiently expanded the fire-pot was removed, the tube and jacket swung round and lowered, as shown in Plate XIV. The length of the screw-bolts was so arranged that, when lowered into position, the pins *b b* (Plate XIV) could be inerted as shown.

The lower section of the bolts *c c* being heated and expanded as soon as the pins *b b* were inserted, the nuts *d d* were screwed tightly home. The sections *c c* were then cooled off quickly while the tunnion-ring was still hot, and the result was a perfect joint between the jacket and trunnion-ring. For the sleeve the process was identical, the only change necessary being in the length of the screw-bolts, and an equally tight joint was obtained.

Time required to heat up sleeve, twenty-five minutes, A play of about .01 inch was allowed in expansion above the dimensions of the corresponding parts.

This arrangement of the bolts, simple as it is, has answered the purpose for which it was intended perfectly and secured a perfect joint, which is not always attainable in shrinking.

After the parts were shrunk together, the gun was removed to the shop, the exterior of the jacket turned to dimensions, except a narrow ring at the rear end, which was used as a bearing in cutting the thread for the base-ring, the sleeve was finished, the key-ring put on, the tube bored up to 3.2 inches, and the gun placed in the rifling machine. Previous to this the bore was accurately measured with the star gauge. The measurements are given in Table No. 2.

The defect in the metal of the tube, which was shown in the first boring about 2 feet from the muzzle, became very apparent during the rifling.

A bur was thrown up on the edges of the lands by the action of the rifling tool and a reamer was made for removing it in preference to lapping, as it was feared the latter process would cut off the sharp driving edges of the lands which it was desired to preserve. This reamer is a cylinder of steel, fitting the bore accurately and having one of its ends beveled slightly and containing the cutters. The reamer was pulled through the bore and turned on its axis, at the same time removing the bur and leaving a smooth, sharp edge on the land.

After the rifling the shot chamber was bored and the powder chamber finished. For boring the shot chamber a bar was made, Plate IX, Figs. 5, *5a*, *5b*, having a cutter the exact shape of the chamber. This bar was centered in the bore by the front bearing *a* (Fig. 5) resting in a cast-iron ring placed in the rear end of the tube at the entrance of the chamber. The screw thread was then cut on the interior of jacket, for the reception of the base-ring, the latter threaded and shrunk into place. The necessary expansion for this purpose was obtained by inserting a piece of hot iron in the rear of the jacket for a short time. The principal object of the shrinkage here was to secure a longitudinal contraction of the jacket, and a close joint in consequence between the rear end of the tube and the corresponding face of the base-ring. The thread on the interior of the base-ring was cut and its alternate sectors planed off before its insertion in the jacket. The time required to finish exterior of gun was twenty-five days of eight hours each, one man being employed. After finish turning on the exterior, the gun was filed and its exterior completed. The lug for the hinge of carrier ring was then cut out at the rear of the jacket. For this purpose the gun was placed in the shaping machine, muzzle down, a hole being cut in the shop floor to allow muzzle to drop through, the gun being supported by a heavy iron ring, which rested on the bed of the shaping machine, the muzzle dropping down through the bed. The lug was finished in this machine, with the exception of a little filing to fit it to the carrier-ring.

Work on the breech mechanism.—The copper bushing for the forward end of the vent was inserted and pressed into place under the screw press. The work on the different parts of the breech mechanism presents nothing worthy of remark.

The time required to finish it was about sixty days of eight hours each, two first-class machinists and one or two helpers being employed.

CHANGES MADE IN THE GUN DURING MANUFACTURE.

The principal changes made in the gun are shown in Plate XI, Fig. 1, showing the gun as originally designed, and Fig. 2 as altered; the other figures giving the details of the alterations.

In Fig. 1 it will be observed that there is a small key-ring in front of the trunnion-ring, shown in detail in Fig. 6. This was removed, as it was thought it weakened the tube, and the sleeve was made as shown in Figs. 2 and 6*a*, a key-ring being screwed on in front of sleeve. Two advantages are claimed for this: first, the tube is not cut into and weakened; and second, the key-ring, extending further to the front, increases the strength of the tube, and it is thought that it adds to the finish of the gun on the exterior. This change was made at the suggestion of the commanding officer, as also that represented in Figs. 5 and 5*a*, the form of the shoulder between jacket and trunnion-ring.

Figs. 4 and 4*a* show, the first the original and the second the finished form of shot chamber. The change was rendered necessary by a change in the form of the copper band on projectile. As originally designed it was suitable for a band like that on the Hotchkiss projectile, but a change to a band of rectangular cross-section necessitated the form shown in Fig. 4*a*.

Fig. 3 shows the V-shaped thread as originally designed, connecting the base-ring and jacket. This was changed to the shape shown in Fig. 3*a*, in order that the strain on the rear of jacket, under the action of the powder, might be parallel to the axis, instead of oblique to it, as in Fig. 3.

When first designed it was the intention to force the parts of the gun into place by pressure in the testing machine. In consequence the jacket, trunnion-ring, and sleeve were to be slightly tapering on the interior. When the plan was changed, and it was decided to shrink the parts together, this taper was no longer necessary, and a change was therefore made in the design of the parts. The tube under the sleeve was increased in thickness at the forward end .02 inch, and a very slight addition was made to the thickness of the jacket at the front and rear, to compensate for this increase in weight. The sleeve also was slightly increased in thickness, as shown in drawing.

Two stay-pins were inserted, one in the key-ring at its junction with the sleeve, and the other in base-ring, to prevent any turning.

It was found in fitting the carrier-ring into place that the shape of the jacket near the hinge was such that the carrier-ring would not swing freely, and this shape was slightly altered by chipping and filing. The position of this hinge and its projection beyond the exterior of the jacket caused a great deal of unnecessary work in cutting it out, and it is thought that its position in future constructions can be changed, so as to give a better fit to carrier-ring and less work in cutting and shaping it. Important changes were made in the breech mechanism, and were all suggested by Mr. John Allen, an experienced workman. They are:

First. A change in the shape of the rear portion of the breech-plug, by which it is left with a full thread, and fits into the carrier-ring accurately, closing up the openings in the screw-threads and keeping out dust and dampness from the parts of the mechanism.

Second. A corresponding change in the carrier-ring, removing the stops from the exterior surface and placing them inside, and thereby simplifying the construction and giving a plane surface to the exterior face of carrier-ring.

Third. A change in the method of locking the carrier-ring to the jacket, substituting the pin and spring already described for the locking-catch used in the De Bange system, the pin being more simple and requiring less work to fit it.

Fourth. Giving a slight taper to the gas check and its seat, in order that it may be ground to an accurate fit.

Fifth. Changing the shape of front edges of head of lever handle, and of its corresponding recess in carrier-ring, in order to correct any tendency of breech-plug to move beyond its proper position after firing, as before explained.

Sixth. Omitting collars at the ends of hinge-pin, which would have necessitated cutting away the metal of jacket, and substituting therefor two stay pins, which hold the hinge-pin in place.

An examination of Table No. 1 will show the care with which the work was done, and how small the variations are from the dimensions given in the drawing.

In Table No. 2 is shown the actual contractions of the tube after the shrinking on of the jacket, trunnion-band, and sleeve. Two diameters were measured, one through the plane of the axis of the trunnions and the other at right angles to this plane. Each series was measured twice, and the figures given are the means of the measurements. These measurements differed very slightly from each other, and it is believed that they are accurate. It will be seen from the table that the contraction is greatest for that portion of the tube in rear of the shoulder and at the front end of powder chamber, or where the metal of the tube is bored out and the jacket thick. Again, it will be noticed that the contraction of the tube under the trunnion-ring, in the plane through the axis of the trunnions, is much greater than that in the plane at right angles to that plane; twice as great by measurement. The plane through the axis of trunnions contains a greater thickness of metal, the trunnions, rimbases, &c., and hence its contractile force in cooling is greater.

The results of these measurements would seem to indicate that in future constructions the parts to be shrunk on should be turned as nearly to finished dimensions as possible, for in the case of the jacket, which was left cylindrical on the exterior, the resulting contraction is too great, as is seen from the table.

The irregularity in the contraction of the trunnion-ring cannot well be avoided, as it would be very difficult to finish it after shrinkage, and would necessitate extra labor and cost.

Respectfully submitted.

LAWRENCE L. BRUFF,
Lieutenant of Ordnance, in charge of gun.

To the COMMANDING OFFICER,
Watertown Arsenal, Mass.

List of plant and tools made and purchased for the construction of the 3.2-inch gun.

MADE AT ARSENAL.

Fitting up shot lathes for boring and rifling tube:
- One piercing tool.
- Forging, turning, and planing tool and bar.
- Forging and turning cutter.
- One boring-bar for boring jacket.
- Forging and turning bar.
- Turning and cutting feed-screw.
- Planing slot for feed-screw.
- Forging, fitting, and turning cutter-head.
- Forging, turning, and cutting gears.
- Making cutters.
- Fitting collars and nut for feed-screw.

Three wood reamers:
- Forging and turning reamers.
- Fitting and turning wood.
- Planing slots for cutters.
- Forging, fitting, and turning cutters.

One boring and rifling machine:
- Making steel spindle for clutch.
- Boring out same for feed-screw.
- Making patterns and casting gears.
- Making patterns and casting gear-frame.
- Making patterns and casting following-rest.
- Boring and planing bearing of following-rest.
- Making pattern and casting box-bearing for screw in following-rest, boring-machine.
- Making pattern and casting box bearing for screw in following-rest, rifling-machine.
- Fitting these bearings.
- Making pattern and casting sliding head.
- Boring and planing bearings of same.
- Making pattern for bronze nut, feed-screw, boring-machine.
- Casting, tapping, finishing, and fitting same in bearing in sliding-head.
- Making pattern for bronze nut, feed-screw, rifling-machine.
- Casting, tapping, finishing, and fitting same in bearing in sliding-head.
- Making pattern and casting for bearing of boring-bar in sliding-head.
- Making same for bearing for rifling-bar in sliding-head.
- Planing and fitting these bearings.
- Turning and finishing pipe for boring-bar and cutting key-way in same.
- Turning and finishing pipe for rifling-bar.
- Putting in and finishing forging at front end of rifling-bar.
- Turning and cutting feed-screw, boring-machine.
- Turning and cutting driving-screw, rifling-machine.
- Turning and finishing spline-shaft.
- Making pattern, casting, and boring bearings for spline-shaft.
- Making pattern, casting, boring, and fitting front bearing for boring-bar.
- Making pattern, casting, boring, and fitting front bearing for rifling-bar.
- Boring and fitting rests for tube on boring and rifling.
- Making shipping rods and levers, rifling-machine.
- Turning, boring, drilling, and fitting index-plate, rifling-machine.
- Forging, turning, and shrinking one wrought-iron collar on rear of rifling-bar.
- Forging, turning, and threading steel pin and bushing for gear next to index-plate.
- The gears for the rifling-machine were cut by Pratt and Whitney.

One rifling-head:
- Forging the head.
- Boring interior.
- Turning exterior, planing out slots for bearings.
- Fitting bearings.
- Making pattern and casting, planing, filing, and fitting front bronze bearing.
- Forging, turning, and planing sliding steel pin.
- Planing slot for sliding-piece carrying cutter.
- Making sliding-piece for cutter.
- Threading front of steel sliding pin.
- Making bearing-nut for sliding-pin.
- Making cutters.

One tool for boring shot-chamber:
  Forging and turning tool.
  Planing slots for cutters.
  Forging, turning, and fitting cutters.
  Making cast-iron bearing-ring.
Apparatus for turning outside of jacket and the powder-chamber:
  Making patterns, casting, planing, and finishing three cast-iron pieces for frame-work.
  Making pattern, casting, boring, finishing, and fitting one tool-holder.
  Forging, turning, and slotting one boring-bar.
  Making and fitting cutter.
  Planing and finishing two steel formers.
  Making lug and attachments for regulating feed.
Shrinking apparatus:
  Making pattern and casting for rest for jacket, trunnion ring, and sleeve.
  Making jacket for cross-head.
  Boring and planing these castings.
  Forging jointed bolts, jaws, and pins.
  Threading same.
  Making gas and water collars.
  Making long rod passing through gun.
  Making fire-pot (boiler iron).

SMALL TOOLS.

1 tap, 1¾ inches.
1 tap, 2 inches.
1 tap, .65 inches.
2 tap, .7 inch.
1 tap, ¾ inch.
1 tap, .5 inch.
1 tap, .5 inch.
1 milling-tool for recess in carrier-ring.
1 drill-socket.
1 holder for drilling cutters for piercing-tool.
1 die, ½-inch.
1 drill, .6-inch.
1 taper reamer for index-plate rifling-machine.
1 taper drill for index-plate.
1 counterbore .7 inch by 1.3 inches for hole in breech-plug.
1 taper countersink, for screws in stops carrier-ring.
1 counterbore, .6 inch by 1.1 inches.
1 wrench for turning index-plate rifling-machine.
1 bur-reamer, ½ inch.
1 countersink, ¼ by ½ inch.
1 countersink, ¼ by ¼ inch.
1 countersink, ½ by .65 inch.
1 countersink, .3 by .65 inch.
1 bur-reamer, .65 inch.
1 countersink, ½ by .65 inch.
1 countersink, ½ by .7 inch.
1 bur-reamer, .4 inch.
1 bur-reamer, .55 inch.
1 bur-reamer, .5 inch.
1 cutter-bar and cutter for hole in breech-plug.
1 taper reamer for stay-pins in carrier-ring.
1 twist-drill, .4 inch.
2 broaches for rifling-head.
3 arbors for rifling-head.
3 screw-arbors for rifling-head.
2 drills for stay pins for base-ring and screw-collar.
1 bottoming drill for hole for latch-pin in jacket.
1 screw-socket.
1 centering-punch.
1 cast-iron ring for guides in filing trunnion.
4 cutters for boring-bar for jacket.
1 3.2-inch bur-reamer for cleaning off burs on lands after rifling.
4 cutters for piercing-tool.
6 cutters for rifling-head.
6 cutters for wood reamers.
1 plug arbor, 3 inches.
5 plug arbors for turning tube.
1 arbor for breech-plug.
2 cast-iron washers. ¼ and ½ inch thick, for fitting base-ring.
2 wing-arbors for turning jacket.
1 screw-plug arbor for turning base-ring.
1 arbor for turning carrier-ring.
2 cast-iron washers for guides in planing off trunnion bands.
1 steel arbor, .65 inch.
1 chuck-ring for holding tube in turning and boring.
1 following-rest for cutting screws for boring and rifling machine.
1 former for spacing index-plate rifling-machine.
1 socket for wood reamer.
1 cast-iron collar for securing on key-ring.
3 snap-gauges, from 3 to 10 inches.
1 strap-rest for piercing-tool.
3 lathe-straps.
2 hook-bolts for trunnions.
8 thread-tools.
1 arbor for breech-plug.
1 wrench for screwing in latch-plug (carrier-ring).

PURCHASED.

1 reamer, $\frac{11}{16}$-inch.
1 reamer, $\frac{7}{16}$-inch.
1 reamer, ⅝-inch.
1 reamer, $\frac{3}{16}$-inch.
1 reamer, ¼-inch.

1 reamer, $\frac{3}{16}$-inch.
1 reamer, $\frac{5}{16}$-inch.
1 reamer, $\frac{9}{16}$-inch.
1 drill, $\frac{3}{4}$ inch.
1 drill, $\frac{7}{16}$-inch.
1 drill, $\frac{3}{8}$-inch.
1 drill, $\frac{9}{16}$-inch.
2 drills, $\frac{5}{8}$-inch.
1 drill, $\frac{3}{16}$ inch.
2 drills, $\frac{3}{16}$-inch.
1 set taps and dies, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{8}$, $\frac{3}{4}$ inch.
1 universal die-stock.
2 tap-wrenches, stock.

Table No. 1.—*Showing actual measurements of exterior of tube and interior of jacket, sleeve, and trunnion-ring, before shrinkage.*

JACKET.

Distance from rear end of jacket.	Exterior diameter tube.	Interior diameter jacket, &c.	Difference of diameter, actual shrinkage.	Prescribed shrinkage.	Difference.
Inches.	*Inches.*	*Inches.*	*Inch.*	*Inch.*	*Inch.*
6.6	6.011	6.002	.009	.009	0
8.6	6.011	6.002	.009	.009	0
10.6	6.011	6.002	.009	.009	0
12.6	6.011	6.0015	.0095	.009	+.0005
14.6	6.011	6.0015	.0095	.009	+.0005
16.6	6.011	6.001	.010	.009	+.001
18.6	6.011	6.001	.010	.009	+.001
20.6	6.010	6.001	.009	.009	0
22.6	6.010	6.0015	.0095	.009	+.0005
*24.6	6.010	6.0	.010	.009	+.001
25.6	5.609	5.601	.008	.0084	−.0004
26.6	5.609	5.601	.008	.0084	−.0004
27.6	5.609	5.601	.008	.0084	−.0004
†28.45	5.609	5.6008	.0082	.0084	−.0002

TRUNNION-RING.

29.45	5.609	5.6	.009	.0084	+.0006
30.45	5.609	5.6	.009	.0084	+.0006
31.45	5.609	5.6008	.0082	.0084	−.0002
32.45	5.600	5.601	.008	.0084	−.0004
33.45	5.61	5.6015	.0095	.0084	+.0011
‡34.45	5.61	5.6018	.0092	.0084	+.0008
....	5.61	5.0018	.0092	.0084	+.0008

SLEEVE.

46.0	5.607	5.598	.009	.0084	+.0006
48	5.606	5.598	.008	.0084	−.0004
50	5.606	5.598	.008	.0084	−.0004
52	5.606	5.598	.008	.0084	−.0004
54	5.607	5.598	.009	.0084	+.0006
56	5.608	5.599	.009	.0084	+.0006
58	5.608	5.599	.009	.0084	+.0006
§59	5.608	5.6	.008	.0084	−.0004

* Shoulder.
† Front of jacket.
‡ End of trunnion-ring.
§ End of sleeve.

Table No. 2.—*Showing the measurements of the tube, with the star gauge, before and after shrinkage, and the actual contractions due to shrinkage.*

Distance from rear end of tube.	Diameters before shrinkage.	Diameters through plane of trunnions after shrinkage.	Diameters perpendicular to plane of trunnions after shrinkage.	Actual contraction.	
				Through trunnions.	Perpendicular to trunnions.
JACKET, REAR OF SHOULDER.					
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inch.*
13.9	3.172	3.166	3.165	.006	.007
14.4	3.172	3.164	3.164	.008	.008
15.4	3.172	3.163	3.163	.009	.009
16.4	3.172	3.160	3.160	.012	.012
17.4	3.172	3.159	3.159	.013	.013
18.4	3.172	3.160	3.159	.012	.013
*19.4	3.172	3.164	3.164	.008	.008
JACKET, FRONT OF SHOULDER.					
20.4	3.172	3.166	3.166	.006	.006
21.4	3.172	3.168	3.168	.004	.004
22.4	3.172	3.169	3.169	.003	.003
†23.4	3.172	3.169	3.169	.003	.003
TRUNNION-RING.					
24.4	3.172	3.167	3.170	.005	.002
25.4	3.172	3.166	3.169	.006	.003
26.4	3.172	3.166	3.169	.006	.003
27.4	3.172	3.166	3.169	.006	.003
28.4	3.172	3.166	3.169	.006	.003
29.4	3.172	3.168	3.170	.004	.002
‡30.4	3.172	3.169	3.170	.003	.002
SLEEVE.					
31.4	3.172	3.170	3.170	.002	.002
32.4	3.172	3.170	3.170	.002	.002
33.4	3.172	3.170	3.170	.002	.002
34.4	3.172	3.171	3.170	.001	.002
35.4	3.172	3.171	3.170	.001	.002
36.4	3.172	3.170	3.170	.002	.002
37.4	3.172	3.170	3.170	.002	.002
38.4	3.172	3.170	3.170	.002	.002
39.4	3.172	3.171	3.171	.001	.001
40.4	3.172	3.171	3.171	.001	.001
41.4	3.172	3.171	3.171	.001	.001
42.4	3.172	3.171	3.171	.001	.001
§43.4	3.172	3.171	3.171	.001	.001
45.4	3.172	3.172	3.172	.000	.000
	Same to muzzle.	Same to muzzle.	Same to muzzle.		

* Shoulder 19 inches from rear of tube.
† Trunnion-ring begins 22.85 inches from rear of tube.
‡ Trunnion-ring ends here; sleeve begins.
§ Sleeve ends here.

Report of inspection and proof of 3.2-inch B. L. steel rifle No. 1, experimental, under order Chief of Ordnance.

Subject of measurement.	Dimensions.		Remarks.
	Prescribed.	Actual.	
Length of gun (total)	90.8	90.8	
Length of bore	83.2	83.2	
Maximum diameter	9.56	9.56	
Length of tube	85.2	85.2	
Exterior diameter of tube for 19 inches from rear.	6.009	6.009	Shrinkage allowed .0015 inch per inch of diameter.
Exterior diameter of tube from 19 inches from rear to 43.70 inches.	5.608	5.608	Do.
Exterior diameter at muzzle	5.10	5.10	
Interior diameter of powder chamber	3.8	3.8	Elliptical, 22.8 inches major axis, 3.8 inches minor axis.
Length of powder chamber	10.0	10.0	
Length of jacket	28.45	28.45	
Maximum exterior diameter of jacket	9.56	9.56	Exterior curved longitudinally.
Minimum exterior diameter of jacket	7.60	7.60	At front end.
Inside diameter from rear to 24.60 inches of jacket.	6.00	6.00	
Inside diameter for 3.85 inches from front end of jacket.	5.60	5.60	
Length of locking shoulder	1.25	1.25	
Exterior diameter at extreme of locking shoulder.	6.602	6.602	Shrinkage allowed, .0015 inch per 1 inch of diam.
Exterior diameter at face of jacket of locking shoulder.	6.559	6.559	
Corresponding diameter of recess in trunnion band.	6.550 6.5928	6.550 6.592	
Length of trunnion-band	8.80	8.80	
Exterior diameter of trunnion-band	7.60	7.60	
Interior diameter of trunnion-band (except locking recess).	5.60	5.60	
Diameter of trunnions	3.80	3.80	
Length of trunnions	2.80	2.80	
Distance between rim-bases	9.50	9.50	
Diameter of rim-bases	4.80	4.80	
Length of base-ring	4.00	4.00	
Diameter of base-ring outside of threads	6.35	6.35	Put in under very slight shrinkage.
Inside diameter of base-ring (breech-plug threads).	4.03	4.03	
Outside, threaded a length of	3.80	3.80	
Inside, threaded a length of	4.00	4.00	
Length of sleeve	13.30	13.30	
Exterior diameter of sleeve	6.60	6.60	
Inside diameter of sleeve	5.60	5.60	
Length of key-ring	3.00	3.00	
Exterior diameter of key-ring	6.50	6.50	
Inside diameter of screw threads of key-ring	5.32	5.32	
Pitch of screw threads of key-ring	0.26	0.26	
Pitch of screw threads of base-ring	0.25	0.25	
Pitch of screw threads of breech-plug	0.40	0.40	
Length of breech-plug (total)	5.95	5.95	
Diameter of breech-plug (outside threads)	4.47	4.47	
Length of rifling	71.525	71.525	
Number of grooves	24	24	
Number of lands	24	24	
Width of lands	.1188	.1188	
Width of grooves	0.30	0.30	
Depth of grooves	0.05	0.05	

Twist, uniform, one turn in 30 calibers=6° angle.
Weight of gun, 791 pounds.
Preponderance, 77 pounds.

3.20" B.L. Steel Field Gun.

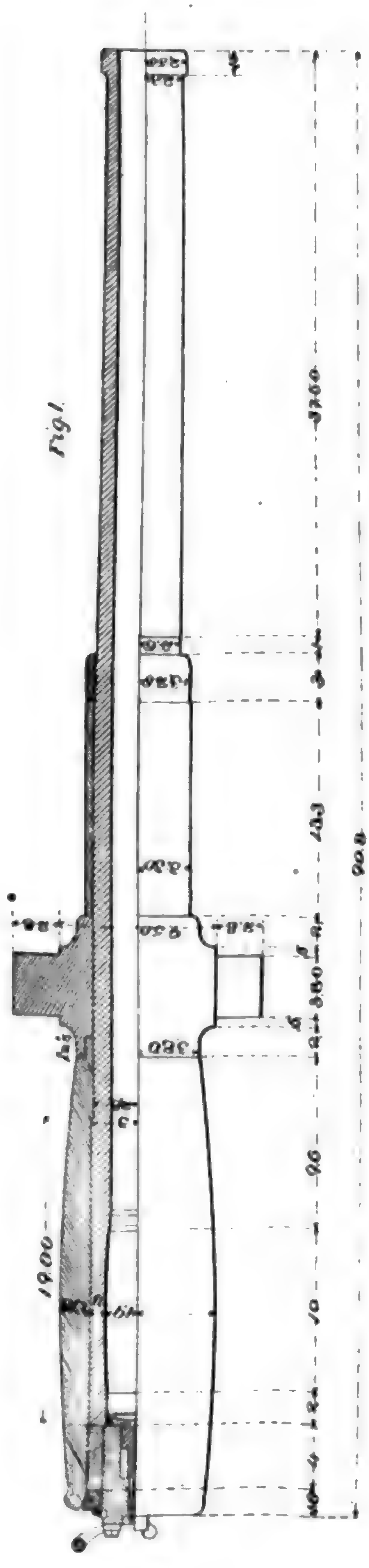
Fig. 1.

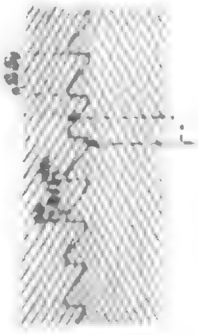
Fig. 2.

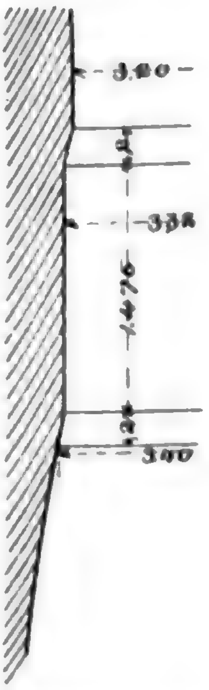
Fig. 3.

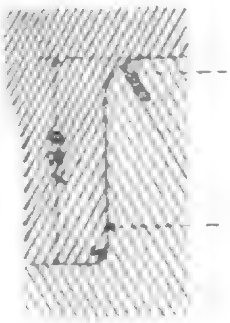
Fig. 4.

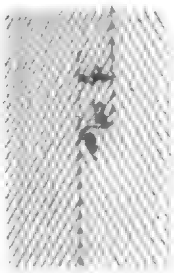
Fig. 5.

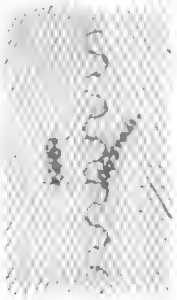
Fig. 6.

PLATE II.

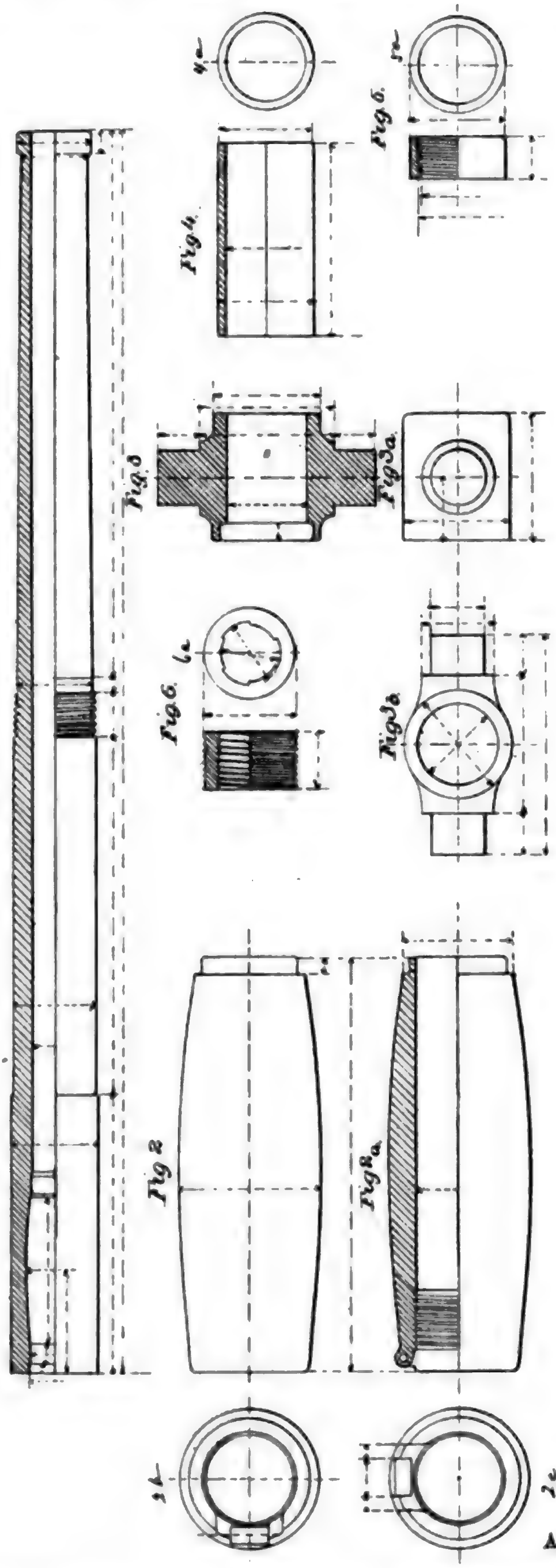

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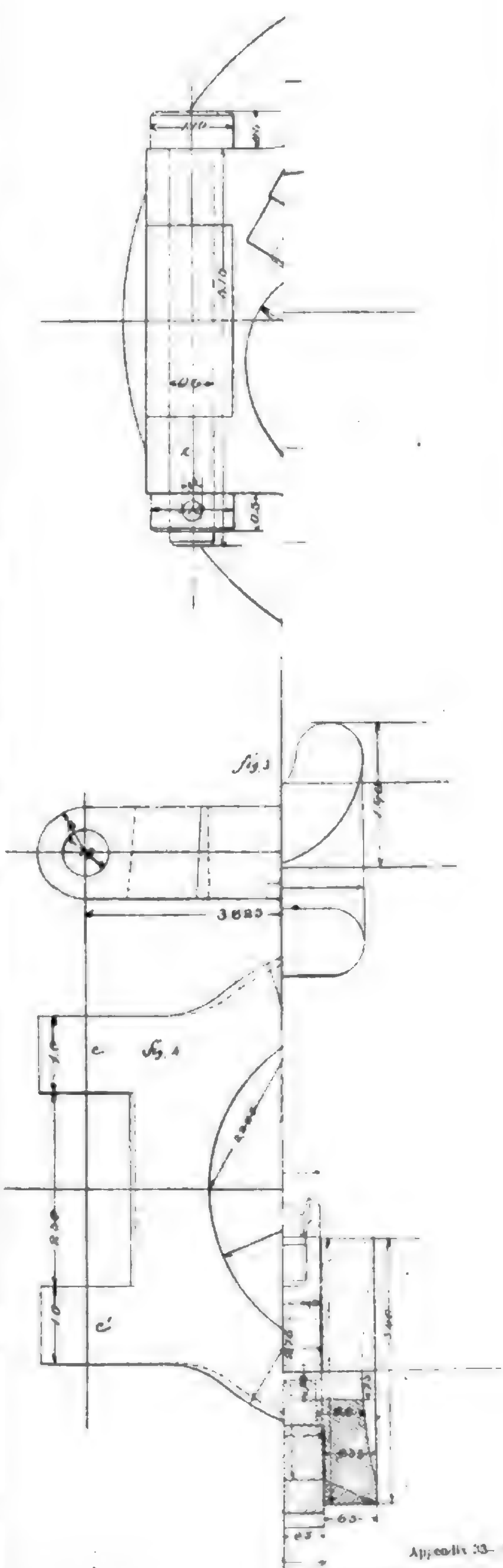
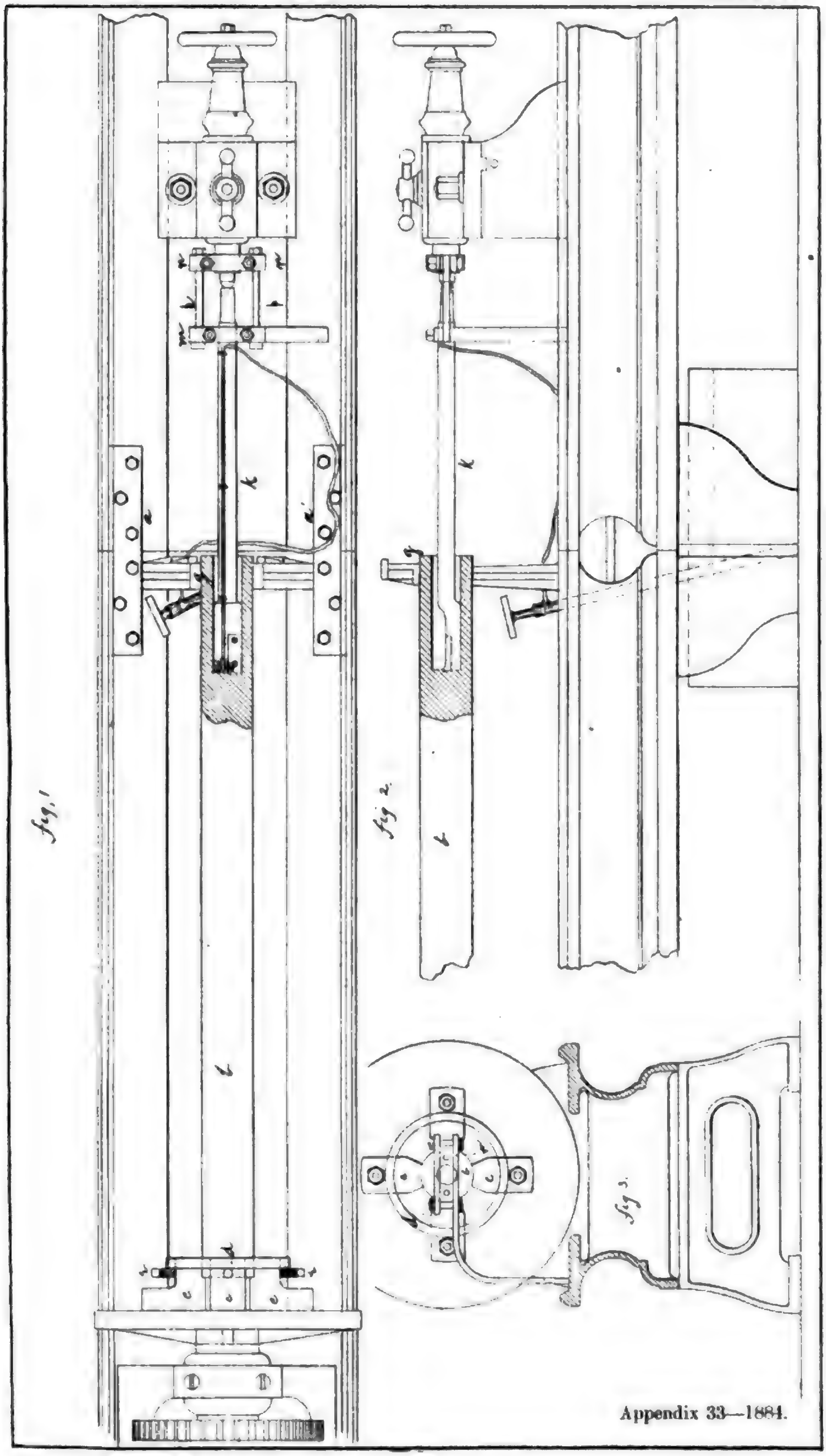
PLATE III.

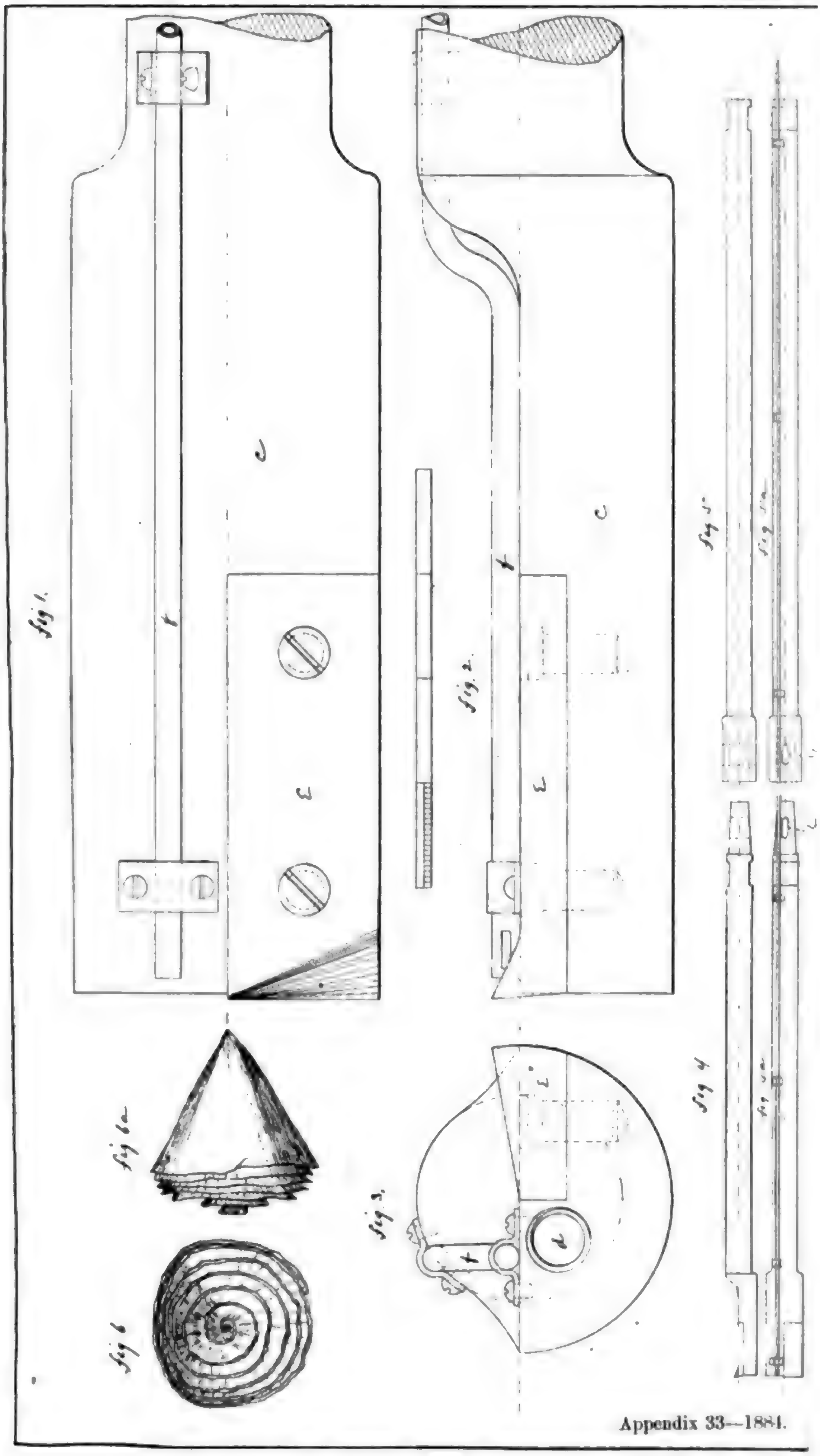


Appendix 33—1884

PLATE IV.



Appendix 33—1884.



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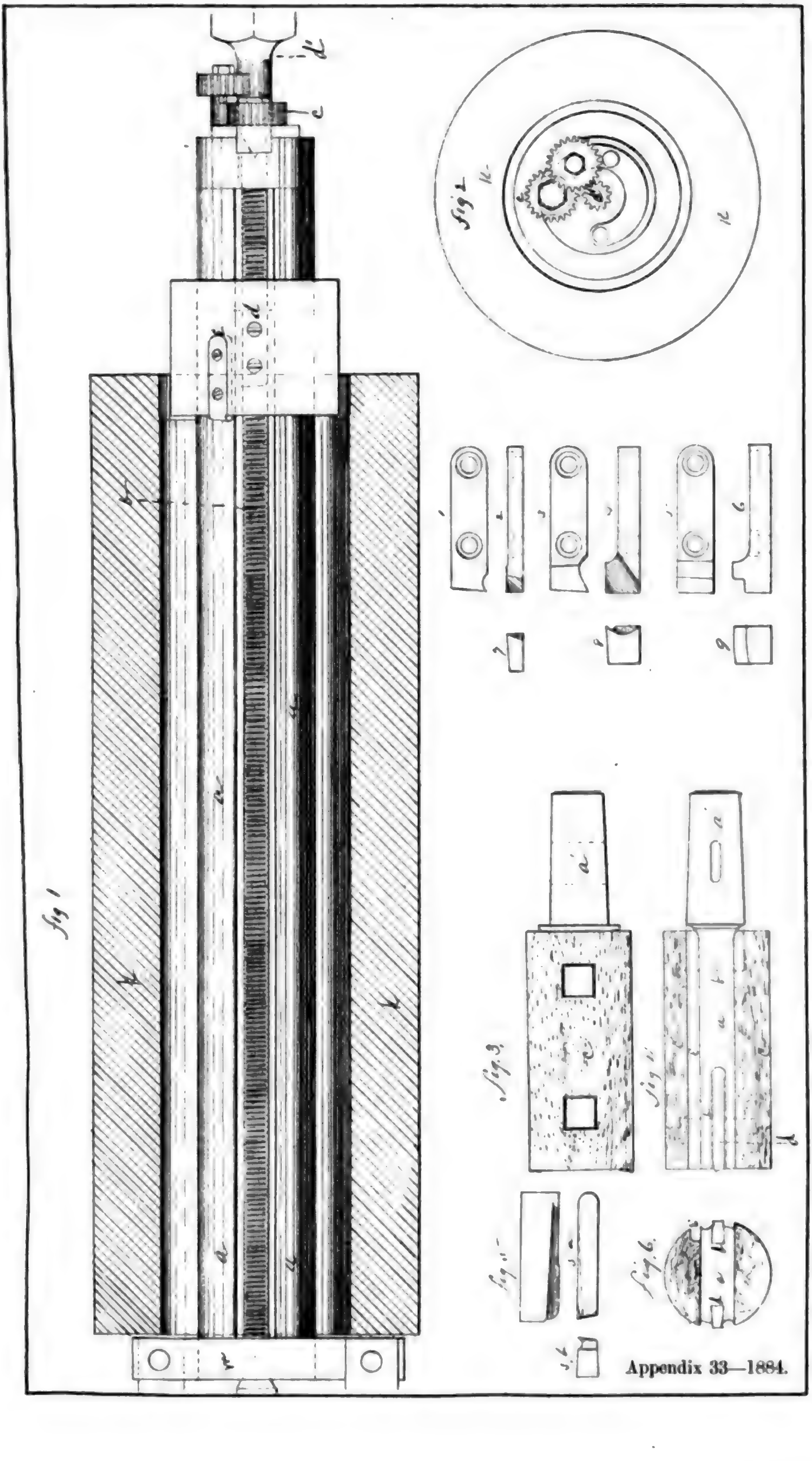
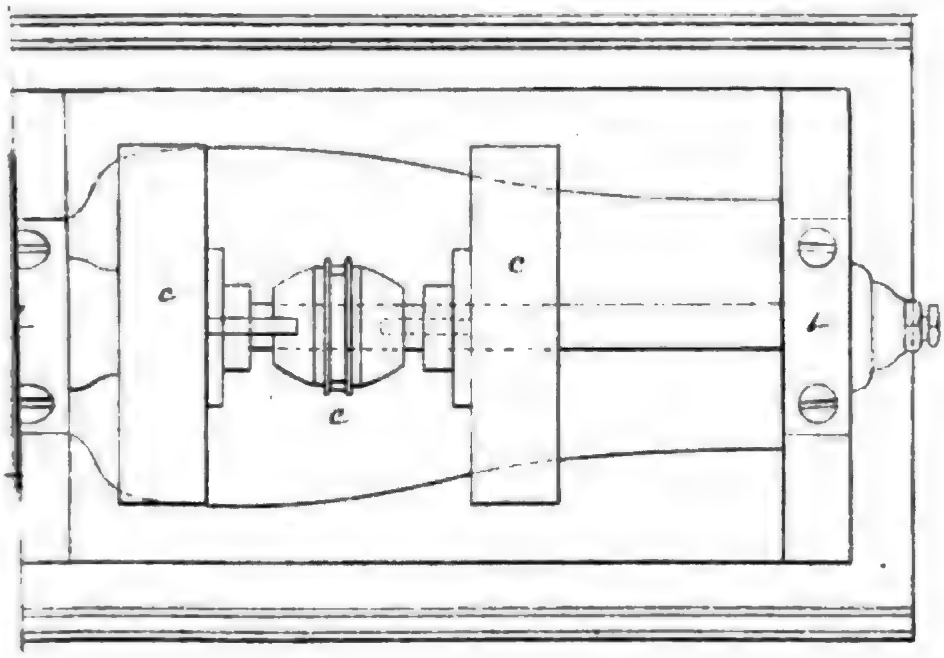


Appendix 33—1884.



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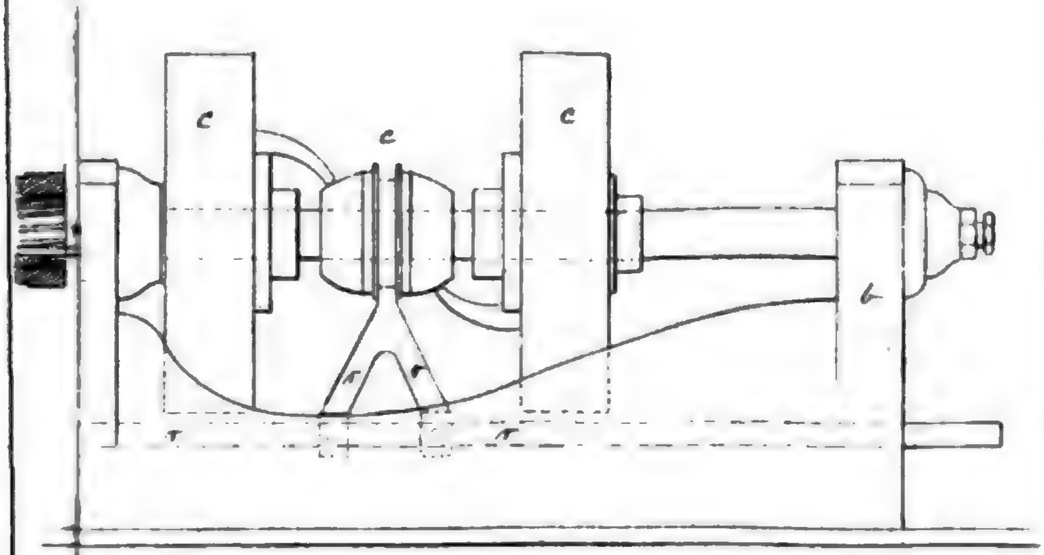

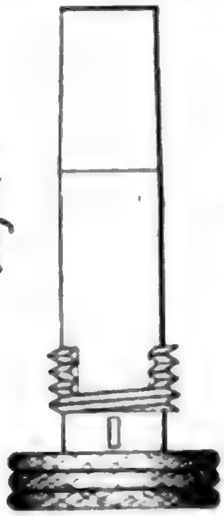

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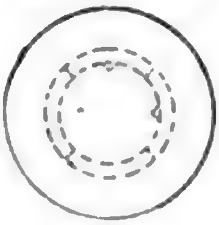

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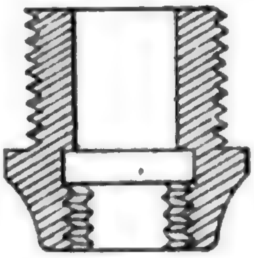

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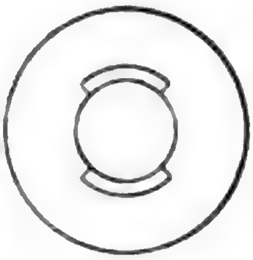

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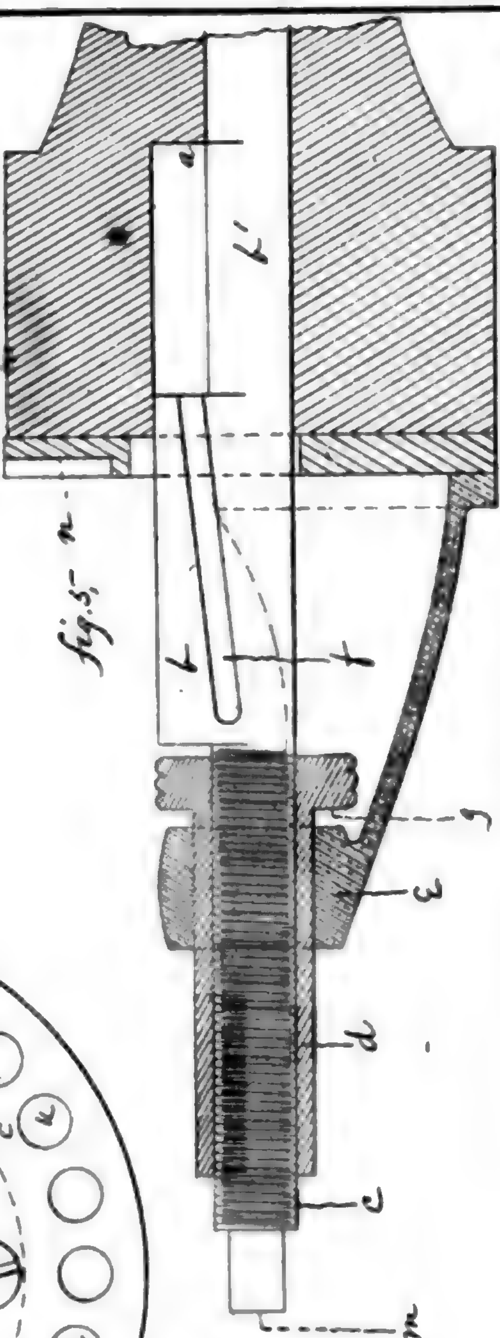

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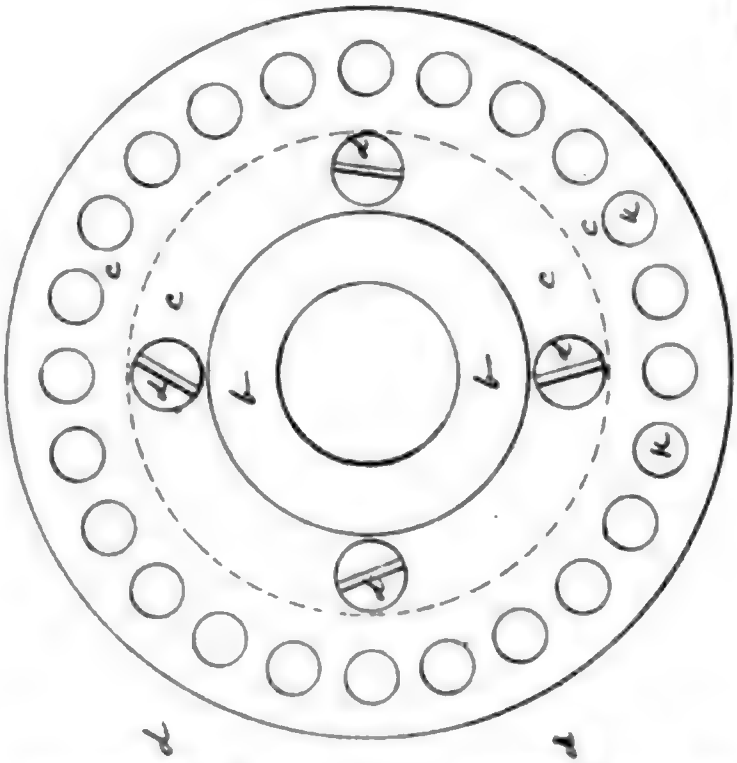

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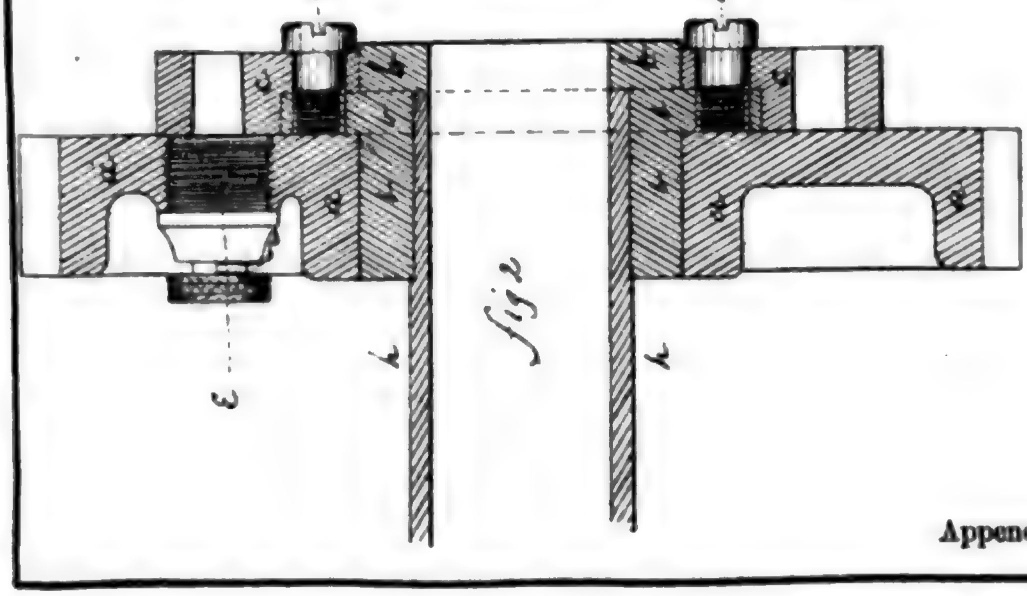
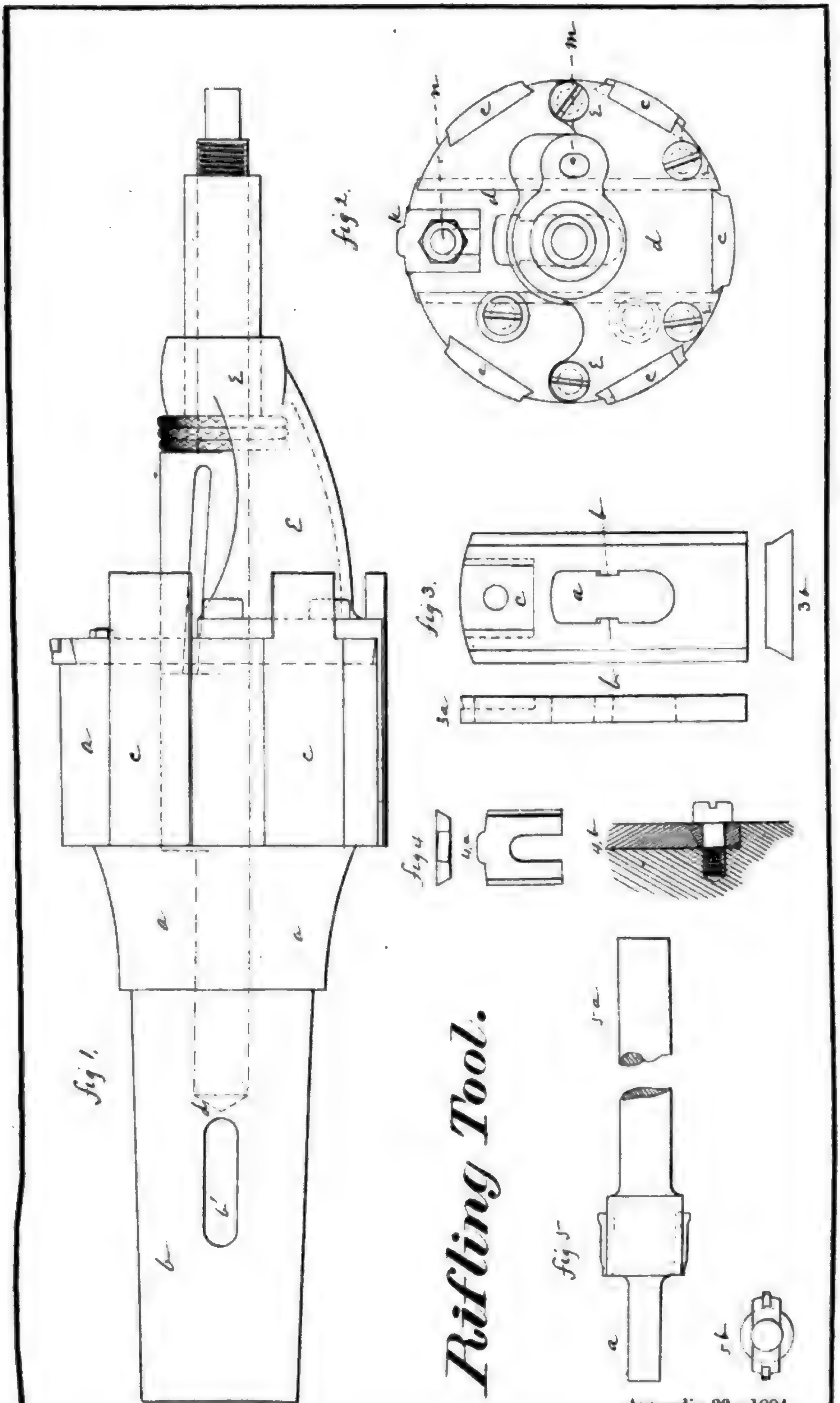


fig 2

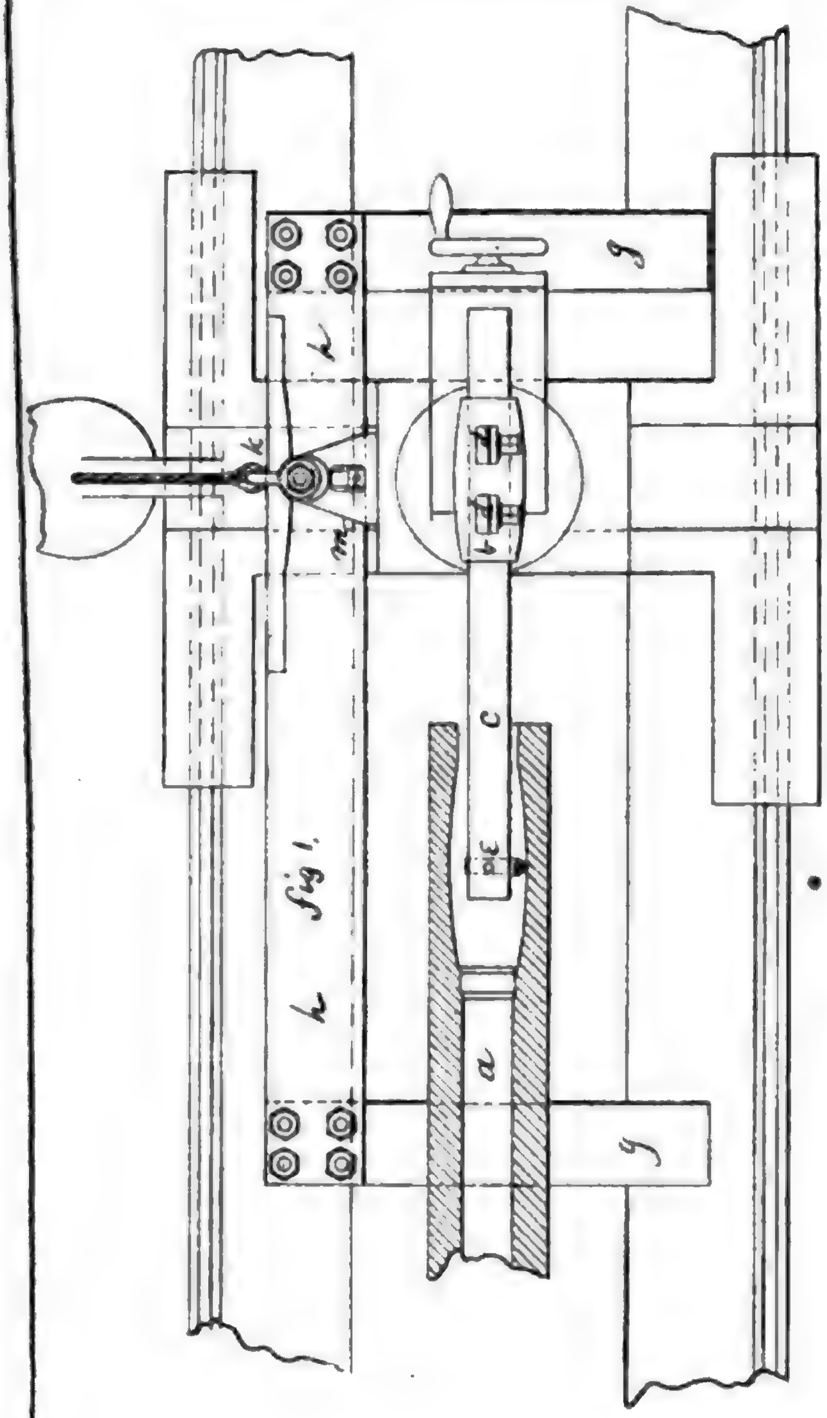
Appendix 33—1884.

PLATE IX.



Rifling Tool.

Appendix 33—1884.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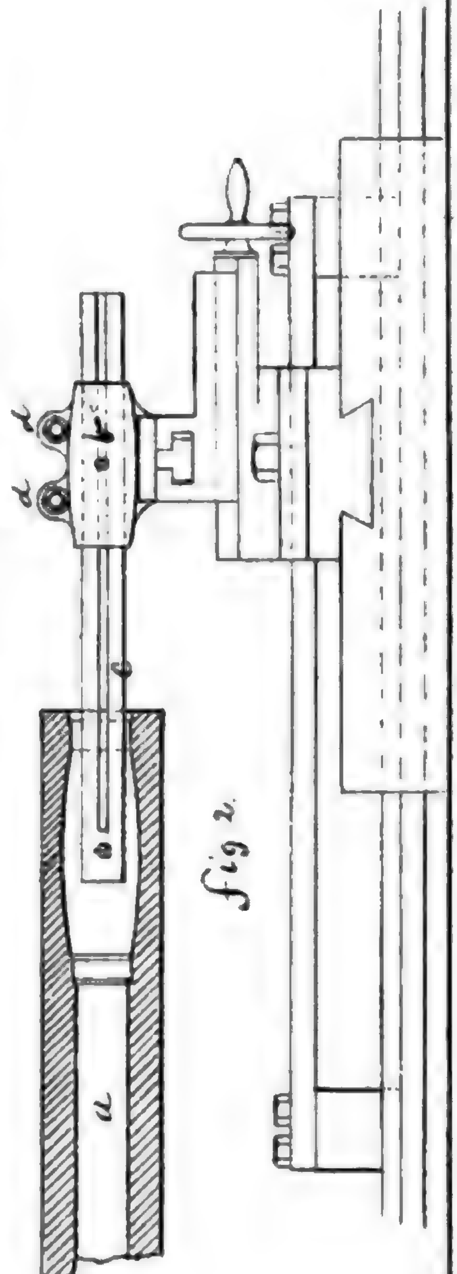
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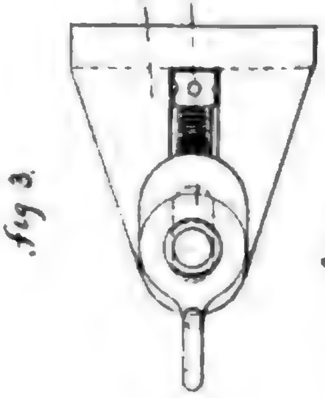
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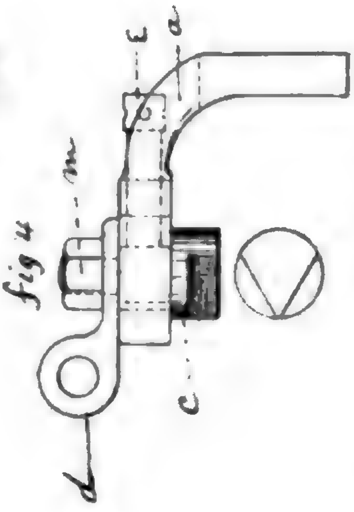
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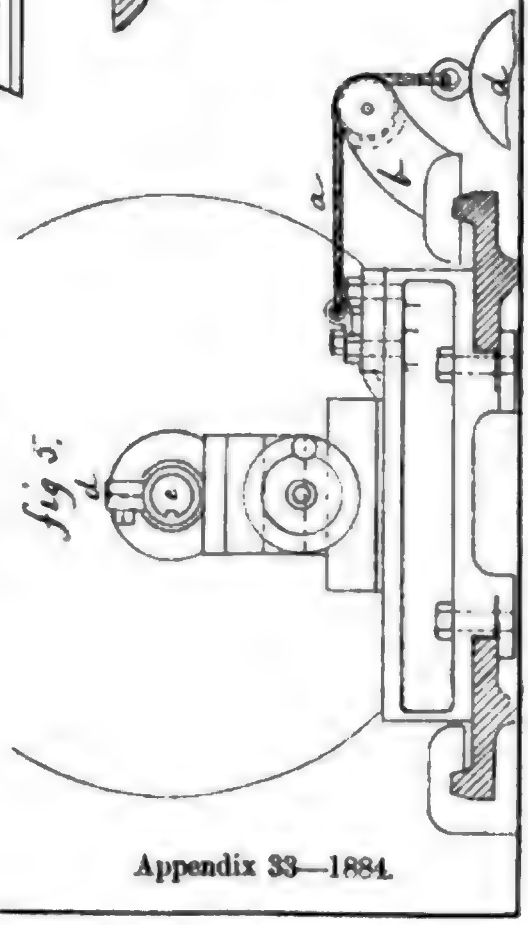
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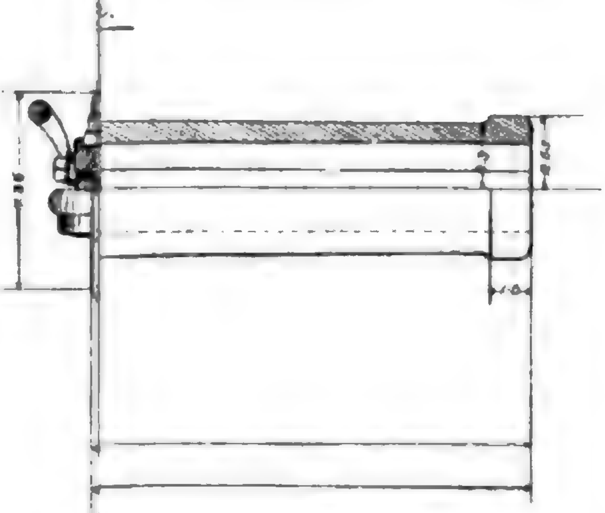
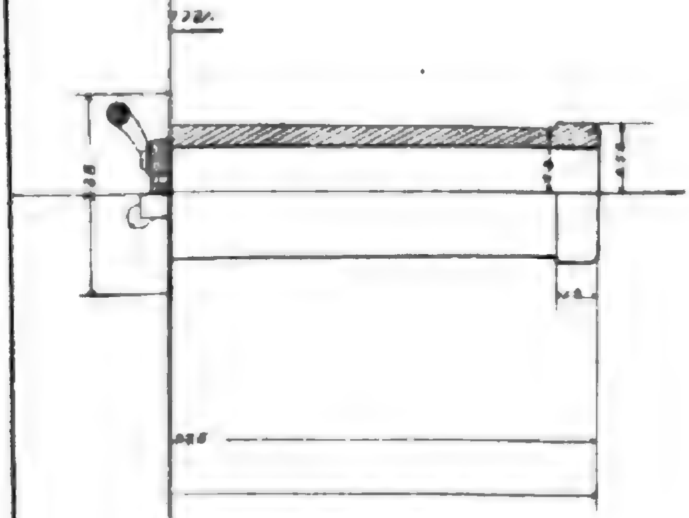
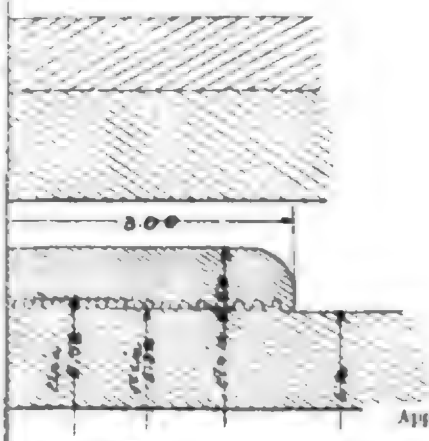
Appendix 33—1884.

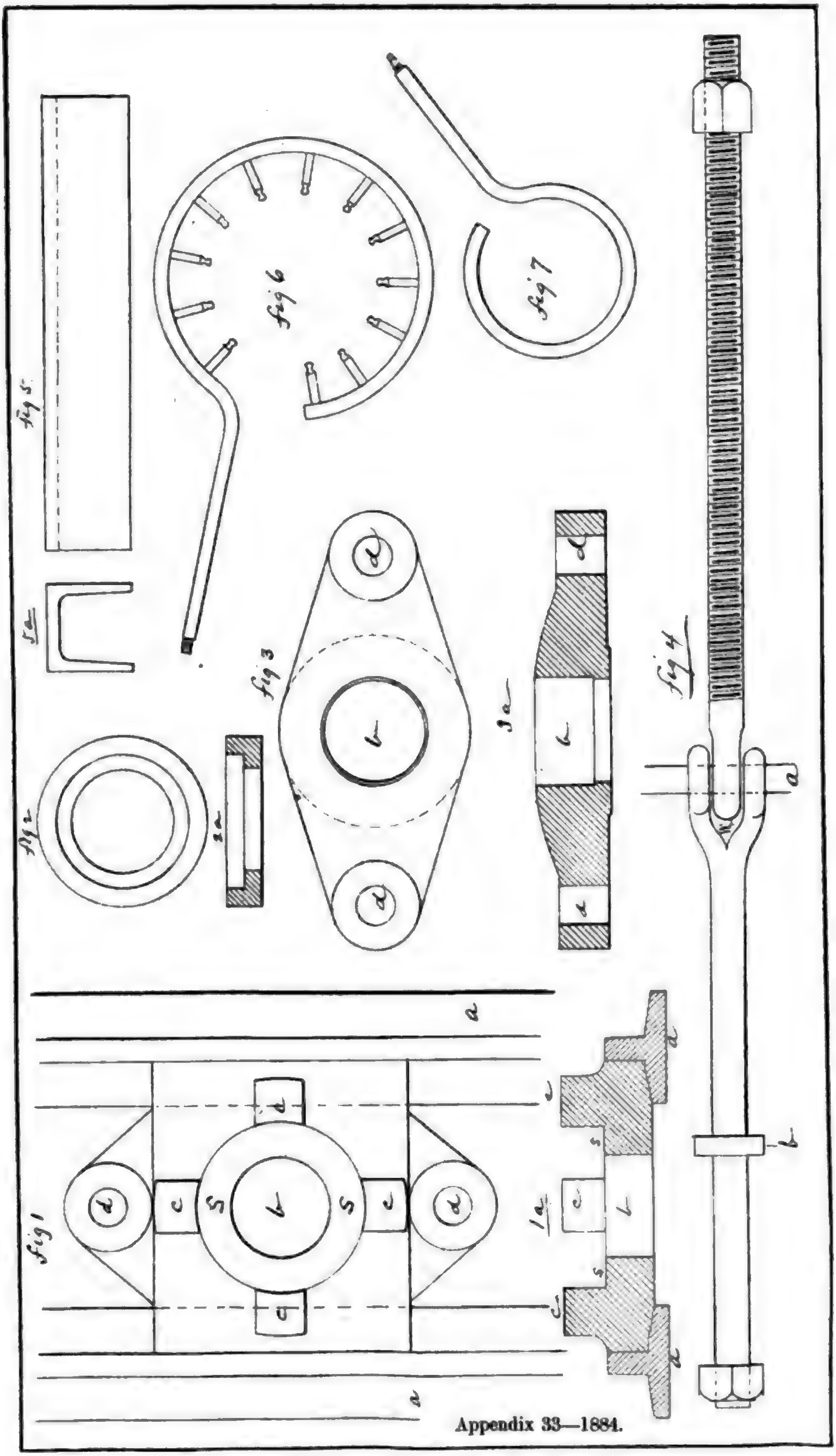
PLATE XI.





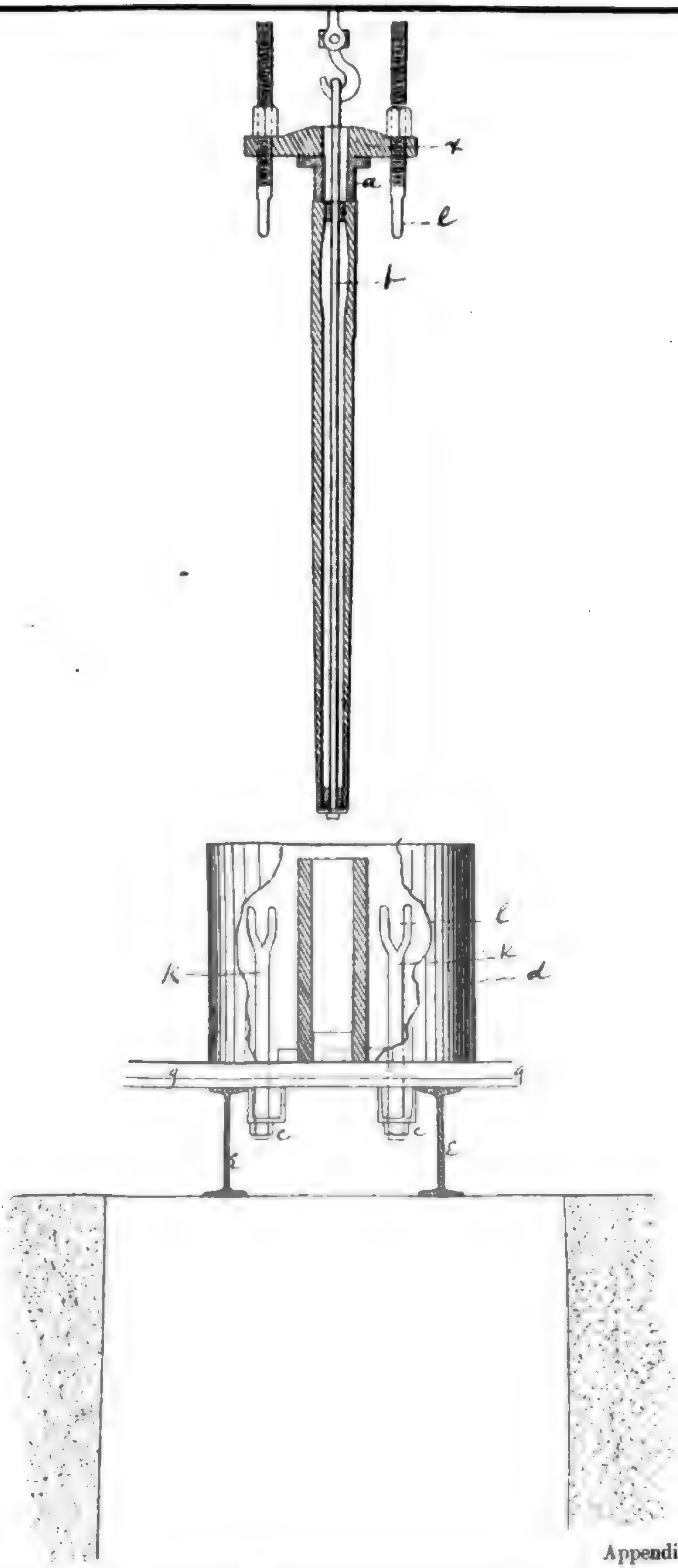


Appendix 33—1884.



Appendix 33—1884.

PLATE XIII.



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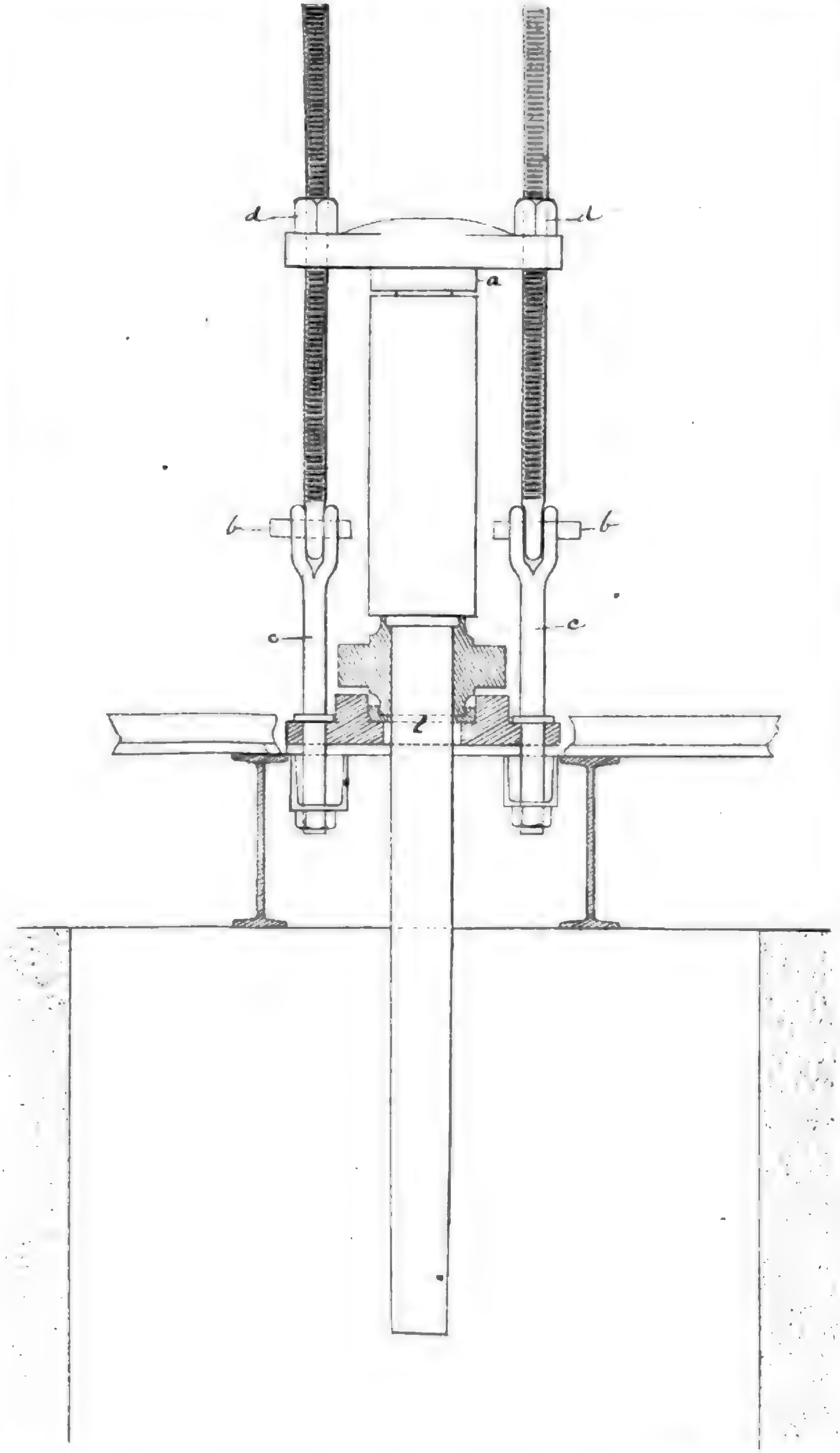
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APPENDIX 34.

REPORT OF THE CONSTRUCTION OF FIELD CARRIAGES FOR 3.2-INCH WROUGHT-IRON BREECH-LOADING RIFLES AT THE WATERVLIET ARSENAL.

(3 plates.)

WATERVLIET ARSENAL, N. Y., *August* 4, 1884.

As the six metal carriages made at this arsenal for service of the 3.2-inch breech-loading rifles obtained by the conversion of 3-inch wrought-iron ordnance rifles must be regarded at present only as experimental, it will be interesting to refer to the steps that resulted in the constructions that have been given to the service for trial.

HISTORY.

The first metal field carriage made by the Ordnance Department and subjected to service with a breech-loading gun was that described in the Report of the Chief of Ordnance, United States Army, for 1880, page 45. The second carriage was that described in the Report of the Chief of Ordnance, United States Army, for 1881, page 411.

The principal difference in these carriages was in the construction of the cheeks and trail. In the second carriage the steel plates used were stiffened by being flanged around their edges, whilst in the first carriage this was effected by angle-iron riveted on the inside along the edges.

These carriages were tested at the Sandy Hook proving ground. The history of the second carriage is as follows:

[Third indorsement.]

THE ORDNANCE BOARD, U. S. A.,
New York, *June* 28, 1881.

Respectfully returned to the Chief of Ordnance, U. S. A.

The trial of this carriage at the Sandy Hook proving ground has now been carried to a point where the principal defects in construction have been developed, the latter portion of the trial in the presence of Colonel Buffington, commanding Watervliet arsenal, with whom the Board consulted as to the changes and modifications deemed advisable in future manufactures.

The main points of weakness, whether of material or construction, are found to exist in the axle, side braces, wheels, the brace for elevating screw, and the hand-spike attachment.

The Board would now recommend that the carriage, with its limber-body, together with the 3.20 inch-B. L. rifle first turned over to the Board, the rifling of which was found to be slightly defective, be sent to Watervliet arsenal to be used, generally speaking, as a guide or basis in the manufacture of the carriages for the 3.20-inch B. L. rifles to be issued for service.

The detailed report on the gun, carriage, projectiles, powder, &c., with copies of firing record and plotted targets, will be forwarded as soon as completed.

For the Board.

T. G. BAYLOR,
Lieutenant-Colonel of Ordnance, Senior Member Present.

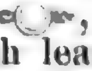
Report on 3.20-inch field carriage, to accompany (eleventh indorsement) Ordnance Office letter No. 939, in accordance with tenth indorsement thereon of Chief of Ordnance.

The carriage made at the Cold Spring foundry, received at Watervliet arsenal from Sandy Hook, was found to be defective as specified in third indorsement of the Ordnance Board on Ordnance Office letter No. 939, and in addition, after arrival at Watervliet, the left cheek, under side, was found to be cracked through the entire flange and ⅜ inch above, a defect that escaped notice at Sandy Hook.

These defects about cover the entire carriage, and leave very little beyond the form and dimensions as a basis to work upon; these conform generally to the 3-inch wooden carriage, except that the pintle of limber is considerably farther to the rear—the position and manner of attachment of the limber-box itself not determined. In view of these facts, as I have had no experience to guide me, suggestions as to alterations and additions are made with some diffidence.

In arriving at the conclusions on which these are based I have had the help and suggestions of the assistant officers of this arsenal; have discussed with them the subject in detail; have embodied, so far as known and other conditions will allow, the views of the Light Artillery Board, which visited this arsenal and examined the carriage with me; have also availed myself of advice and views of a member, Col. E. B. Williston, of said Board, now present (since) at the arsenal.

I, at first, deemed it necessary to apply to this carriage some device for relieving it of the initial shock of recoil, but nothing comprising the simplicity, efficiency, and durability necessary for our service has occurred to me—the devices of the Englehardt and Gruson (Albini) carriages not, in my judgment, meeting the necessities of the case; at least such constructions should not be resorted to until it is shown that a *light* axle cannot be made strong enough.

The axle, therefore, is the first consideration, and I propose to turn cylindrically the present one, which is partly cylindrical and partly conical, down to its smallest diameter, 3 inches at the shoulder washers, and rivet over it, through uniting flanges closely fitting, two steel boiler plates .25 inch in thickness, one above, the other below, giving a cross-section, thus, , the rear flange so shaped as to give the greatest strength with least weight. This construction would remove ¾ inch of metal from axle between the cheeks and two conical portions increasing from 0 to ½ inch in thickness, the weight of which, added to the weight of the heavy braces and attachments—which it is desirable to eliminate—and weight of cheek understraps, rendered unnecessary, would, perhaps, about equal the weight of added plates and rivets.

The sides forming cheeks and trail are fashioned after the Krupp field carriage, namely, sheets of steel cut to form and then flanged, with this difference, Krupp's are flanged by heating each plate as a whole and striking up the flange in a die—one operation; whereas the plates of this carriage have been heated part at a time and hammered over by hand, a costly and unsatisfactory operation attended by more or less injury to the metal; to this mode of fabrication may be attributed the crack across the flange above referred to. Riveting angle-irons to plane-plates was tried in the first carriage made—the one at Watervliet arsenal being the second one—but the product was found too heavy.

Therefore, without considering the crack as an evidence of weakness, but fault of construction, not having the plant necessary to form the flanges as Krupp's are, resort must be had to some form that will give the necessary strength and lightness—less cost following as a result of the mode of construction.

I have learned that although the Department allowed but $800 to be paid the West Point foundry the two carriages made there cost about $1,200 each. For the cheeks and trail-plates it is proposed to use about ¼-inch steel plates of similar form, without flanges, except for a short distance in vicinity of trunnion-beds on top and axle on the bottom—short angle-irons replacing flanges in front—the remainder to within a short distance of these flanges, to be, in cross-section, a segment of a circle, whose radius would about equal one described, with its center on a perpendicular to center of cross-section at any point, to take in this center and the two end points of flanges of corresponding cross-section of present carriage thus, ⊢—. For the idea of curving the plates I am indebted to Captain Varney. The double elevating screw and its manner of attachment to cheeks is essentially the same as the Austrian, page 465, Plate IV, Report of Chief of Ordnance for 1877. Without considering the weakness, as shown by the breaking of its attachments, it is objectionable in that it will not permit the elevation, 30°, desired by the Light Artillery Board; it is also objectionable in that it may be rendered unserviceable by an accidental blow or rifle shot on the thread, particularly of the smaller screw. For an elevating device I propose a simple lever *eyed* to the rear flange of axle-plates and passing through a fixture attached to gun at curve of breech in rear of fermeture, similar to that used with oscillating and elevating lever of Gatling gun; 30 or more degrees of elevation, if desired, can be obtained in this way, and the device offers obvious advantages in the way of cost, simplicity, lightness, and ease of manufacture. The brake used is essentially the same as the Prussian, page 535, Fig. 40 (Report of Chief of Ordnance for 1877). This is objectionable if it is to be used for checking recoil, in that it consumes time to apply and release it in action, the position of the screw, being under the gun in front, is not convenient, and the bar passing under the trail, far to the rear, is in the way in the service of the piece, particularly when limbering up. For a brake for recoil and down hill, and to serve as a mud scraper for wheels. I propose an iron or steel bar or rod *eyed* to the shoulder washer of axle at one end, the other end being a flanged shoe forged on in such a way that when the bar is held up vertically (the position of the eye being on top of axle) the shoe can be passed outwardly over the tire and, when in this position, the bar be thrown to the front or rear—falling by its own weight—the shoe will fall upon the tire, with flange outside, overlapping it. After making a part revolution the wheels by this arrangement would be held firmly, the carriage sliding until recoil ceases. It would be automatic; thrown to the rear in firing it would break the recoil; to the rear on the march it would be a mud scraper for the wheel;

to the front on the march it would brake down hill. When not in use it would be carried vertically, fastened to the seat on gun axle. Two, one for each wheel, would be placed on the carriage. Going down hill it would be sufficient to brake but one wheel. Should this proposed brake be found to check *rolling* recoil too suddenly a stiff, short spring of this shape fastened at its center to inside of shoe may be added, or to insure an elastic system it would be well to make this addition at the start.

The Archibald wheel, as recommended by the Light Artillery Board, is considered to fill the requirements of our service.

I propose to place the center of limber-box over center of axle, and key it to the body and hounds, as in present field carriage.

The body of limber to be built similarly to the one shown in Report of Chief of Ordnance for 1877, Fig. 39 of Colonel Benton's report, the pintle hook to be placed as near to the limber-box as possible consistent with the conditions of its attachment to the angle-irons of the body. This position, it is thought, will give an angle between pole and trail sufficiently great to turn in a small space and relieve, as far as other necessary conditions will permit, the horses from the weight of body and pole when limbered up.

The axle and brake must be tested first, and it is to be regretted that there are not facilities at Watervliet arsenal for firing at an elevation. To fire at all, a sand butt must be made, and as the sand would have to be hauled some distance, the cost would be considerable.

Should the proposed changes be approved, the cost, beyond that of the plates for the axle, would be comparatively little; provided it be thought sufficient to test the axle, using the brake independently of the body of carriage—a six-pounder wooden stock and cheeks could be used for the test. Axle and brake once established, the problem of making a sufficiently simple and strong body would not be difficult.

Respectfully submitted.

A. R. BUFFINGTON,
Lieutenant-Colonel of Ordnance, Commanding.

Report of the trial of a carriage of metal for 3.20-inch B. L. rifle, at Watervliet arsenal, April, 1882.

Twelve rounds were fired; at the last the carriage was rendered unfit for use by the left trunnion-plate becoming detached from the cheek by the shearing off of the rivets that secured the plate.

The axle withstood the strain perfectly, no distortion whatever being perceptible.

The brakes controlled the recoil within desired limits; the carriage at some fires bounded from the ground twice, the trail being at first pressed forcibly into the ground, the wheels finally sliding several feet; the ground was loam, covered with sod.

As the trunnion-plate had resisted all firing with the original brake, its failure with this firing must have been due to the new brake. The cap-squares bent somewhat at each fire at low elevation. The elevating apparatus might not have broken had no motion taken place in the trunnion-beds, but this apparatus is, in my judgment, for several reasons, unsuited to the gun. With any elevating apparatus the cheeks of the carriage prevent over 15° of elevation being obtained, whereas, in Lieutenant-Colonel Buffington's Report, accompanying eleventh indorsement, Ordnance Office letter 939, of 1881, he refers to 30° of elevation, possibly, being desired. Should any such elevation as that be given to the piece, the strength of the axle as now constructed would be questionable, as the bracing is placed to resist a horizontal and not a vertical component of pressure.

A. MORDECAI,
Major of Ordnance, Commanding.

WATERVLIET ARSENAL, *April* 26, 1882.

Record of firing with 3.20-inch B. L. rifle, to test carriage of metal made under the Constructor of Ordnance, U. S. A., for field service—carriage modified by Lt. Col. A. R. Buffington, Ordnance Department.

No. of fire.	Time.	Powder.		Projectile.		Elevation.	Recoil.	Brakes.	Remarks.
		Kind.	Weight.	Kind.	Weight.				
	1882.		*Lbs.*		*Lbs. oz.*	°	′ ″		
1	April 19	I. K. (A.)	3	Hotchkiss hollow shot.	12 11	6	5 10	Each held vertical before firing by being wired to a spoke and thus kept from contact with wheel till after recoil began.	Right bolt attaching elevating fixture to gun broke off; slight distortion of trunnion-plates and cap-squares.
2	April 19	I. K. (A.)	3		12 11	6	7		Left bolt attaching elevating fixture to gun broke off, rendering elevating apparatus useless; distortion of cap-square increased; right brake fell off wheel.
3	April 19	I. K. (A.)	3		12 11	6	5 10		
4	April 19	I. K. (A.)	3		12 11	6	6 3		
5	April 19	I. K. (A.)	3		12 11	6	5 3	Each placed in contact with wheel before firing.	Distortion of cap-square increased.
6	April 19	I. K. (A.)	3		12 11	....	6 6		
7	April 19	I. K. (A.)	3		12 11	....	5 3		
8	April 19	I. K. (A.)	3		12 11	....	6 8		
9	April 19	I. K. (A.)	3		12 11	13	7		
10	April 19	I. K. (A.)	3		12 11	13¼	6 6		
11	April 19	I. K. (A.)	3		12 11	13½	6 2		
12	April 19	I. K. (A.)	3		12 11	2	7 6		The three rivets attaching left trunnion-plate to cheek were sheared off.

[Nineteenth indorsement.]

WATERVLIET ARSENAL, *July* 22, 1882.

Respectfully returned to the Chief of Ordnance, U. S. A.

After consultation with Lieutenant-Colonel Buffington I am of the opinion that his views, which in my judgment are worthy of trial, can be applied to the carriage now at this arsenal; these features relate to the recoil check and the elevating apparatus.

To obtain the elevation indicated by the Light Artillery Board as being desirable, it will be necessary to cut away part of the angle-iron along the upper edge of the cheeks and stock; should the carriage be weakened too much by this, I propose to restore its stiffness by riveting pieces of channel-iron on the exterior of the stock. The cheeks of the carriage have been warped by firing; they will have to be straightened, and new trunnion-beds made; these last will be formed in plates of iron or steel extended down sufficiently to strengthen the cheeks.

The elevating apparatus proposed will consist of a seat for the breech of the gun, attached to two arms, which will extend to the rear within the stock and be secured thereto by one long bolt; through a cross-piece at the front end of the arms will pass a screw, its general direction being horizontal, and its front end attached in rear of the axle; the screw and the arms will constitute, as it were, two of the sides of a triangle, the altitude of which will regulate the elevation of the piece; the gun resting on the apex.

The recoil check now on the carriage is to be slightly altered in shape and to be provided with a spring to overcome the want of elasticity in the system.

The present carriage might, should it meet with the views of the Bureau, be used to test these special features; but it is the opinion of Lieutenant-Colonel Buffington and myself that a new carriage with cheeks and trail formed differently will be required for introduction into the service.

The cost of altering the carriage here will depend greatly upon the ease with which its form can be restored, and the necessary stiffness be obtained; it is very difficult to state what the cost may be, but it probably would not exceed $200.

A. MORDECAI,
Major of Ordnance, Commanding.

When I assumed command of this arsenal, November 2, 1881, after Lieutenant-Colonel Buffington had been relieved therefrom, the carriage referred to in the preceding indorsements was ready for trial, but was awaiting the manufacture of the necessary projectiles.

Before the ammunition was received winter had commenced, and it was not until April, 1882, that the weather permitted of the carriage being taken for trial to the New York State rifle range at Bath, near Albany.

The result of this firing is set forth in the report.

This trial developed the fact that the attachment of the trunnion-plates to the cheeks was not sufficiently strong, and also, in my opinion, showed that the elevating apparatus proposed by Lieutenant-Colonel Buffington was not suited to such a gun.

In the consultation referred to in the preceding indorsement, No. 19, Lieutenant Colonel Buffington deemed an elastic brake-rod desirable, and the heavy spiral spring in a metal housing was proposed by me.

The trial of the altered carriage referred to was commenced at the Sandy Hook proving ground, November 21, 1882. Lieutenant-Colonel Buffington and I were present. The record of that firing is given in the Report of the Chief of Ordnance for 1883, pages 326 and 327, and a description of the carriage, denoted as No. 1, is given in the same report, page 319.

At this trial Lieutenant-Colonel Buffington did not consider the spiral spring and housing on brake-rod satisfactory, and later proposed to me a brake-rod which he characterized as "simpler, less expensive, more durable, and would give better results if properly made." It consisted of a flat bar of low steel, spring temper, bent into broad corrugations, whose axes were perpendicular to the length of the bar, thus providing for the extension and contraction of the bar, as in a spiral spring.

As the spring tried with the carriage had given such good results, and as I doubted the successful operation of the new device, it was not tried by me in the construction of carriages made subsequently.

The continued trial of carriage No. 1 proved the success of the alterations relating to the axle, brake, and cheeks. The flanging of the metal plates of this carriage had been a difficult and expensive operation, and the manufacture of carriages upon this plan would necessitate a special furnace and a large hydraulic press. In view of these facts, and of experiments that had been made in England with carriages of different construction, I suggested to the Bureau that the first metal carriage made by the Department might be altered for trial.

The action taken in this matter is shown by the following letter and its indorsements:

WATERVLIET ARSENAL,
West Troy, N. Y., December 21, 1882.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I would respectfully suggest for the consideration of the Bureau the practicability of altering the first metal field carriage made for the 3.18-inch B. L. rifle, described in the report of the Chief of Ordnance for 1880, in such a manner as to render it sufficiently strong and better adapted than it is at present to meet the requirements of service.

The changes proposed would be:

1. Substitute a new steel axle fitted with Archibald wheels, like those that have been obtained for the experimental artillery carriages in course of fabrication at this arsenal.
2. Apply to the axle two steel plates, as used by Lieutenant-Colonel Buffington on the 3.20-inch carriage No. 2, altered here recently.
3. Add the spring wheel-brakes, as on carriage No. 2.
4. Strengthen the cheeks of the carriage by steel castings, as on carriage No. 2.

The carriage so altered would, it is believed, be strong and serviceable, and would give a construction more simple and cheaper than that of carriage No. 2.

The trial of the carriage, the trail being of steel plates stiffened by angle-irons riveted on, would be of value in connection with experiments made in England, reported by Mr. H. J. Butter, pages 14 and 15, Ordnance Notes, No. 195.

Very respectfully, your obedient servant,

A. MORDECAI,
Major of Ordnance, Commanding.

[Second indorsement.]

THE ORDNANCE BOARD, U. S. A.,
New York, January 2, 1883.

Respectfully returned to the Chief of Ordnance, U. S. A.

Experiments at Sandy Hook indicate that the wooden carriages provided with trails of perfectly sound material, with a new box of wrought-iron or cast-steel for the elevating screw, and with the spring brakes proposed by Lieutenant-Colonel Buffington, will be serviceable with the 3.20-inch guns firing a 2½ pound charge.

In the opinion of the Board, however, metal field-carriages similar to the one within referred to, and modified as suggested by Lieutenant-Colonel Mordecai, are deemed far superior, and, when tried in actual service, would give valuable information not to be obtained with the wooden carriage, and therefore recommends that 6 of these carriages be manufactured for the 3.20-inch guns on hand as early as practicable, to replace the wooden ones, if it is deemed advisable to issue the latter temporarily. If this recommendation is approved gun carriage No. 1, now at Sandy Hook, should be sent where the carriages are to be manufactured.

For the Board.

T. G. BAYLOR,
Lieutenant-Colonel of Ordnance, President of the Board.

[Third indorsement.]

ORDNANCE OFFICE, *January 4, 1883.*

Respectfully returned to the commanding officer of Watervliet Arsenal, with instructions to make 6 metal field-gun carriages without limbers, as recommended by the Ordnance Board in preceding indorsement.

It is desired that they be made without delay so that they can be issued early in the spring. The Ordnance Board has been instructed to send him the experimental metal field-gun carriage from Sandy Hook.

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

To comply with the instructions in the preceding indorsement, steps were at once taken to commence as soon as practicable the fabrication of metal field carriages.

Several manufacturers were called upon to state the quality of steel plates and axles they could furnish and the time within which delivery could be made.

The trail plates and axles were ordered February 5, 1883; the former were received at the arsenal by March 15 and the latter by March 21.

Some delay occurred in determining the proper dimensions of the axle-plates, and it was not until February 20 that orders were given to the Albany and Rensselaer Iron and Steel Company, of Troy, for the manufacture of the cast-iron dies necessary to form the plates. The dies were only completed the middle of April, and the plates were delivered by April 26.

As the exact form of the cheeks had to be fixed and patterns made, an order for these castings and those for the lunettes was not given to the founders till February 27; it was the 6th of April before any of these castings were received.

In the mean time, as this arsenal was not prepared for the work to be taken in hand, machines had to be repaired and fitted up and templets and tools made, so that it was the middle of April before the carriages were fully under way.

On June 18, 1883, the Chief of Ordnance was requested to authorize the first of the six carriages, then about completed, to be sent to the Sandy Hook proving ground for trial by the Ordnance Board, to test the elevating apparatus and to develop any marked points of weakness that might exist.

The carriage was received at Sandy Hook June 26, and was tried by the Ordnance Board. The report upon this trial appears in the Report of the Chief of Ordnance United States Army, for 1883, page 313.

The report of the Board was concurred in by the Chief of Orndance and was transmitted July 6, 1883, to the commanding officer, Watervliet Arsenal, with directions to take "the necessary action to cover the objections raised by the Board in regard to the brake."

The points of objection referred to were:

1. The trail handspike is too light, and while the method of attachment is considered the best yet submitted to the Board, it is believed that a wooden handspike with the same attachment would not be susceptible to bending from its own inertia and would be easier to handle.

2. The brakes should not terminate in an eye, but in a hook with a link over the opening to secure it. Thus arranged it may be more readily replaced if injured.

3. The guide rods for the head of the elevating screw should be prevented from separating at their junction with the trunnions. This was effected here by "burring" up the ends of these small trunnions projecting from the head.

4. It is not known whether or not the brakes are intended as a substitute for the chain in locking the carriage when passing over a declivity. If so, it is thought that there may be difficulty in releasing them, as is usually done when near the end of the descent; that it may be necessary for this purpose to stop and back the carriage, which would be a troublesome operation in any case, and impracticable if several carriages were in column.

The steps taken to correct the defects noted above were:

1. The stem of the handspike, embraced within the iron pipe, was lengthened, and by means of strips of hard wood was made to fill the cross-section of the pipe. This, it was thought, would overcome the difficulty, and the work had progressed too far for an economical introduction of a wooden handspike.

2. A hook with a link and pin or key was placed upon all the brakes.

3. The guide-rods for elevating screw were secured on the trunnions

by nuts. The two rods are in addition held together by a separator whose ends pass through the rods and terminate in a thread and nut. If found necessary in service the ends of the trunnions beyond the nuts can be "burred" to prevent nuts from possibly working loose.

4. Though Lieutenant-Colonel Buffington was strongly of the opinion that the brake for checking recoil was entirely suited for use in traveling, it was thought best to provide other means, and the last four carriages finished were fitted with a steel shoe and iron lock-chain.

The general construction of the six carriages was the same, with the exception that three had no axle seats for cannoneers, and two had trail handspikes of wood, with pointing-rings.

Some slight differences in the brakes and elevating screw guides will be noted hereafter.

NOMENCLATURE.

(Plates I, II, and III.)

1 axle.
2 axle-plates, attached about axle by 45 rivets.
2 brake eyes.
2 linch washers.
2 linchpins, including 2 clasps and 2 rivets.
2 cheek and trail plates.
2 cheeks, attached to cheek and trail plates each by 13 rivets, and to axle-plates each by 2 bolts without nuts.
2 angle frames, attached to cheek and trail plates each by 53 rivets, and to axle-plates each by 2 bolts and 2 nuts.
1 lunette, attached to trail by 10 rivets.
1 front transom, attached to cheeks by 2 rivets at each end.
1 middle transom, attached to sides of trail by 3 bolts and 3 nuts at each end.
1 rear transom, attached to sides of trail by 2 bolts and 2 nuts at each end.
1 under transom, attached to sides of trail by 2 bolts and 2 nuts at each end.
1 tie-bolt, 1 nut, 1 separator.
2 cap-squares.
2 chin-bolts.
2 key-bolts.
2 keys, 2 key chains, 2 rings, 2 eye-pins.
2 trail-handles, 3 bolts (1 long, 2 short), 3 nuts.
2 foot attachments for handspike, one with 1 fixed pin, one with 1 movable pin, and 1 key; 4 bolts without nuts.
1 trail-handspike, composed of—
    1 body.
    1 casing (piece of gas pipe).
    1 cap.
    2 strips of wood for filling.
    4 rivets.
1 cross-bar with 1 Y for supporting handspike when turned up, attached to trail by 1 rivet at each end.
1 tool-box, composed of—
    1 bottom plate, attached to trail by 8 rivets.
    1 upper end plate attached to trail and bottom by 6 rivets.
    1 lower end plate attached to trail, bottom, and cross-piece by 8 rivets.

  - 1 cross-piece with eye-stud for lock, attached to trail by 2 rivets; 1 lid, 1 hinge, and 1 hinge-plate united and attached to trail and upper end plate by 11 rivets; 1 padlock; 1 chain fastened by 1 eye-pin riveted to cross-bar for Y.
  - 1 block into which are cut recesses for tools.
- 1 elevating apparatus, composed of—
  - 1 large screw.
  - 1 small screw.
  - 1 nut, 2 key-plates, and 2 screws.
  - 1 large gear-wheel.
  - 1 small gear-wheel.
  - 1 shaft, 2 nuts.
  - 1 hand-wheel.
  - 2 journal boxes, formed each of 1 plate to which a boss is riveted.
  - 3 bolts and 3 nuts.
  - 2 guide-bars.
  - 1 tie-bolt and 2 nuts; 1 separator.
  - 1 elevating-screw bolt and 2 nuts.
- 2 recoil-brakes, composed each of—
  - 1 front bar with hook, 1 link.
  - 1 pin.
  - 1 rear bar with shoe, 1 nut, 1 pin.
  - 1 housing, 1 pin, 1 key, 1 key-screw.
  - 1 spring.
- 2 axle-seats, composed each of—
  - 1 bottom.
  - 4 standards, attached to bottom each by 2 rivets.
  - 1 upper band, attached to standards by 8 rivets.
  - 1 lower band, attached to standards by 8 rivets.
  - 3 springs, attached to seat each by 2 rivets, and to axle-plates each by 2 bolts and 2 nuts.
- 1 foot-rest for right seat (carriage limbered), composed of—
  - 1 side bar.
  - 2 cross-bars.
  - 6 rivets.
- 1 foot-rest for left seat (carriage limbered), composed of—
  - 2 step-bars terminating at upper end in hinge, fastened to axle-plates each by 2 bolts and 2 nuts.
  - 1 step-plate, attached to bars by 12 rivets.
  - 1 tie-chain and 1 toggle, fastened to bottom of seat by 1 bridle and 2 rivets.
- 1 traveling brake, composed of—
  - 1 shoe; 1 ring.
  - 1 lock chain, in three parts; 1 toggle.
  - 1 loose ring.
  - 1 eye-bolt, 1 washer, 1 nut.
  - 1 securing pin, riveted into axle-plates.

ATTACHMENTS.

For sponges and rammers.

- 1 D-ring, 1 plate, 2 staples, 2 rivets, by which plate is attached to cheek.
- 1 foot-ring, attached to cheek by one of the middle transom bolts, and to axle-plates by one of the seat spring bolts.
- 2 hooks riveted into sides of trail.

For recoil brakes.

2 chains and hasps.
2 eye-plates, attached to trail each by 2 rivets.
2 turnbuckles, riveted to 2 studs, which are riveted to trail.
2 wheels, composed each of—
    1 hub.
    1 front flange.
    1 hub-band.
    8 hub-bolts and 8 nuts.
    16 spokes.
    8 fellies.
    16 felly rivets and burs.
    8 dowels.
    1 tire.
    8 tire-bolts, 8 nuts, and 8 washers.

MATERIALS.

With the view of reducing the dimensions of the parts, and thus diminish the weight without detriment to strength, steel was employed, except where no advantage could be gained thereby.

The materials used and the parties by whom manufactured were, in general, as follows, viz:

Axles.—Steel, open-hearth, from Midvale Steel Works, Nicetown, Pa.

Axle-plates.—Steel, Bessemer, "dead soft," Albany and Rensselaer Iron and Steel Company, Troy, N. Y.

Cheek and trail plates.—Steel, open-hearth; 6 from Nashua Iron and Steel Company, Nashua, N. H., and 6 from Otis Iron and Steel Company, Cleveland, Ohio.

Cheeks.—Steel, cast and annealed, from Chester Steel Castings Company, Chester, Pa.

Angle-frames.—Steel, Bessemer, "common stock," Albany and Rensselaer Iron and Steel Company.

Lunettes.—Five, steel, cast, and annealed, Chester Steel Castings Company; 1 wrought iron, best hammered, forged at arsenal.

Transoms.—Steel, Bessemer, "common stock," Albany and Rensselaer Iron and Steel Company.

Cap-squares and chin and key bolts.—Steel, open-hearth, Naylor & Co., Boston, Mass.; made for the purpose.

Brake-eyes.—Steel, very tough, suitable for sledge-hammers; from stock on hand at arsenal.

Tool-box.—Steel, homogeneous, open-hearth, Park, Brother & Co., Pittsburgh, Pa.

ELEVATING APPARATUS.

Screws.—Steel, open-hearth, Gautier Steel Department, Cambria Iron Company, Johnstown, Pa.

Nuts, gear-wheels, and hand-wheels.—Bronze; cast at arsenal.

Journal-boxes.—Plates of wrought iron, rolled; bosses of wrought iron, hammered; all of good quality.

RECOIL BRAKES.

Front bar.—Wrought iron, Norway.

Rear bar.—Steel, open-hearth, Naylor & Co.; made for the purpose.

Housing.—Wrought iron, good quality.

Spring.—Spring steel, best.

AXLE-SEATS.

Bottoms.—Steel, homogeneous, open-hearth, Park, Brother & Co.

Standards.—Wrought iron, Burden's best.

Upper band.—Copper, cold-rolled.

Lower band.—Steel, open-hearth, Naylor & Co.

Springs.—Spring steel.

Foot-rest bars.—Wrought iron, common.

Foot-rest plates.—Steel, open-hearth, Naylor & Co.

Rivets.—Wrought iron, of good quality, Burden Iron Company, Troy, N. Y.

Bolts.—Steel and Norway iron.

Nuts.—Wrought iron, cold-pressed.

Minor parts.—Steel, Norway iron, and Burden's irons, "B. B." and "H. B. & S."

Shoe of traveling brake.—Steel, suitable for sledge-hammers.

WHEELS, ARCHIBALD PATTERN.

(Made by Archibald Wheel Company, Lawrence, Mass.)

Hub, flange, and band.—Cast iron, Gray, best quality.

Spokes and fellies.—Oak.

Dowels.—Wrought iron.

Tires.—Steel.

CONSTRUCTION.

The axles as received were forged to general shape; the arms, shoulders, and body were turned, the latter to a true cylinder 3 inches in diameter.

The axle-plates were by the manufacturers rolled in plates three-eighths of an inch thick and then given the required form by dies under a heavy steam-hammer. Great care was necessary to prevent these plates from warping and cooling. True contact between the axle and plates was obtained by planing the groove in the plates with a tool whose section was that of the axle. The plates were then cut to shape, drilled, and the recesses made for the brake-eye tangs.

The brake-eyes were dovetailed into the shoulders of the axle; lateral movement was prevented by the plates, which also, by fitting over a horizontal tang to the base of the eye, secured the axle from possible rotation within the plates.

After all parts had been accurately fitted the plates were riveted about the axles.

The cheek and trail plates, five-sixteenths of an inch thick, were obtained in a trapezoidal shape. A plate was first cut to required form, determined by a templet; it was then bent to the proper angle along the line on which the cheek and angle-frame join; next the cheek and the angle-frame were fitted to the plate, the rivet-holes drilled, and these parts riveted together.

The angle-frame was formed from a bar of angle steel 1½ inch by 1½ inch, bent at the point of the trail, where a part of one flange was cut away, and the required shape was given the frame on a former.

The cheek and trail plates, with the parts that had been riveted to them, were now brought together and united by temporary attachments till the lunette and front transom had been riveted in place; the other transoms were then fitted and secured by their bolts.

The chin and key bolts and the cap squares were next fitted, and then the trunnion-beds and cap-squares, and the axle-beds, both of which beds form part of the cheeks, were bored out in a lathe.

To diminish as much as possible the weight on the trail, the trunnion-beds are placed as far as appears advisable in front of the axis of the axle.

The body of the carriage was attached to the axle after the surfaces of contact along the cheeks had been planed. The bolts drew these parts to a true bearing.

The elevating apparatus is similar in general construction to one used in the Italian field artillery, but the arrangement of the nut and gear-wheels was suggested by Mr. A. P. Casey, then master machinist at the arsenal, without any knowledge that it had been used before.

The outer screw, which is rotated by the large gear-wheel, serves as a nut to the inner screw, and the latter is prevented from turning by the guide-bars. A spline in the large gear-wheel working in a groove in the outside of the large screw causes these two to turn together, the screw moving through the nut and the wheel; the two key-plates with their screws secure the large gear-wheel in contact with the nut.

The nut, being journaled to the trail, carries with it the screws, gear-wheels, shaft, and hand-wheel.

The guide-bars, straight rods, are attached to the inner elevating screw by the nuts on each end of the bolt that passes through the head of the screw; the front ends of these bars are secured by nuts to prolongations of the upper bolts that attach the middle transom.

On the recoil-brakes the shoes are made of extra thickness at the heel, that being a point at which some previously made showed weakness. The springs are of bars $\frac{5}{16}$ inch square; they were tested and compressed, that a permanent set might, if possible, be given to them; the force required to compress them was about 1,400 pounds, the variation not being great. A shoulder upon the interior of the housing prevents the spring from closing upon itself. The nut on the rear bar is prevented from turning by a pin inserted parallel to the length of the bar. The link over the hook is held in place by a pin through the point of the hook.

The axle-seats, being entirely experimental, were not placed upon all the carriages; wherever introduced one was faced to the front, the other to the rear, that the best position might be determined by trial.

It was thought that for breech-loading guns the cannonier might ride facing to the front; a more agreeable position and one allowing the rest for the feet to be simple and above the axle.

The traveling brake has a stout steel shoe, with short sides raised at the points where the tire and felly will bear; the lock-chain is of the same construction as that used on the present siege-gun carriage, allowing the shoe to be removed from the wheel without stopping the carriage.

It is believed that the necessity for a shoe is marked, as the weight of the carriage and gun is such that with a simple lock-chain the tire of the wheel would soon be worn out. A traveling brake operated by a lever or screw was considered too complicated and heavy for such a carriage.

The Light Artillery Board of 1881 recommended that wheels of the Archibald pattern should be tried on field carriages, and they were therefore used.

The Archibald Wheel Company claims for their wheels the following:

> By means of our patent press process of manufacture, every joint in both spokes and fellies is pressed together with such force and accuracy that, with the stock we use, our wheels will stand always in any climate.
>
> Our stock is invariably seasoned two years under cover in the single spoke and felly.
>
> Each wheel is put together with a pressure twenty-five times greater than any weight it will have on it afterwards, and consequently it cannot be crushed by overloading.
>
> On account of this pressure the spokes can never "work in the hub," nor can any moisture get within the hub to rust or rot the spokes.
>
> They will stand more abuse and climatic changes than any other wheel.
>
> Tires properly put on need never be reset, in any climate, until worn out.
>
> They will run easier and longer on the same oiling than any other wheel, as they are perfectly true in all respects.
>
> To replace a box and that portion of the hub attached:
>
> Unscrew and remove the front hub-band, take off the hub-nuts, and the box will easily drive out. The box is as easily put on again, after which screw on the front hub-band. The tire being on will hold the wood part so that it cannot move while the hub is being taken off. This hub or box is as firm and true on the wheel as was the first one. It can be done by anybody, and in a few moments' time, and at less expense than any other box, and cannot be done wrong.
>
> To replace a spoke:
>
> After the tire and felly on the injured spoke are taken off (and in taking off this felly it is not necessary, on account of the peculiar dowel used, to start off any other felly), take out only the bolt that passes through the injured spoke; saw off this spoke as close to the hub as possible, and bore or dig out the spoke; drive in the duplicate spoke as far as possible, and arrange the tenon at the felly so that the tire may press the spoke about one-eighth inch farther into the hub, and after the tire is on, put in the hub-bolt.

The wheels for these carriages have tires of steel one-half inch thick, the edges rounded and extending beyond the faces of the fellies.

The dowels used with these wheels are triangular pieces of flat wrought iron.

Each carriage is provided with attachments for 2 short sponges and rammers, and the tool boxes are arranged for 1 cold chisel, 1 file 8 inches long, 1 riveting-hammer, 1 oiler, 1 pin-driver, 1 bar-wrench, and 1 screw-wrench, all secured to the block by loops and buttons.

DIFFERENCES OF CONSTRUCTION.

The carriages are numbered from 1 to 6, inclusive, stamped on front edge of cheek.

The preceding nomenclature and description and the drawings apply strictly to No. 3. In this one the cheek and trail plates are of Nashua steel.

No. 1 has no seats; the brake-housings have no stop, the springs being allowed to close upon themselves; the link on one brake is secured by a pin, on the other by a wedge passing under the link; the brake-eyes are lighter than on No. 3. The axle-plates are of "common stock;" the cheek and trail plates of Otis steel. The sponges and rammers are carried one on each side of trail.

No. 2. The cheek and trail plates are, one of Otis; the other of Nashua steel; the lunette is of wrought iron.

No. 4 has no seats; the guide-bars to elevating screw are not straight, and have no tie-bolt and separator; the brake links are secured by wedges. The shoe of the right brake (carriage limbered) has riveted to the outer surface a piece of sheet iron, bent to triangular form; the brake being placed to the rear of the wheel when traveling, the iron rests near the surface of the tire, and serves for a mud-scraper; the brake is prevented from being carried over the wheel by a chain hooked to the shoe by an eye-pin and ring, the other end being welded into a ring in an eye-pin riveted to the axle-plates; this chain when not in use with mud-scraper is passed through a ring in a second eye-pin in axle-plates and thus secured. The mud-scraper is a design of Lieutenant-Colonel Buffington.

The trail handspike is of iron, with two pointing-rings, same as on wooden field-gun carriages; two are carried, one on each side of trail, with a sponge and rammer above them; the front end of handspike passes through a ring hinged to a stud bolted to the axle plates; the rear end is secured by a ring and hook as with the rammer. The cheek and trail plates are of Otis steel.

No. 5. The brake housings have no stop for spring; the brake-links are secured by wedges.

The guide-bars are straight, but have no tie-bolt and separator.

Has no traveling brake. The cheek and trail plates are, one of Otis, the other of Nashua steel.

No. 6 has no seats; the brake-housings have no stop for spring:

The brake links are secured by wedges.

The guide bars are not straight, but have a tie-bolt and separator.

The brake-eyes are lighter than on No. 3. The trail handspike is of wood; it and its attachments are the same as on No. 4. Has no traveling brake.

DIMENSIONS AND WEIGHTS.

DIMENSIONS.

	Inches.
Distance between inside of trunnion-beds	9.52
Diameter of trunnion-holes	3.7
Distance of axis of trunnions in front of axis of axle, piece unlimbered, on horizontal ground	2.75
Distance from axis of trunnions to axis of axle in a straight line	14.25
Height of axis of trunnions above the ground	42.75
Distance, perpendicular to axle, between the points of contact of trail and wheels with the ground	72.5
Distance, horizontal, from front of wheels to end of trail, piece unlimbered	116.25
Distance of the muzzle of the piece, axis horizontal, in front of wheels, piece unlimbered	15.415
Length of carriage without wheels	104
Whole length of axle	75.45
Track of the wheels	60
Height of wheel	57.5
Dish of wheel	1
Vertical field of fire above the horizontal line ... degrees	22
Vertical field of fire below the horizontal line ... do	6

WEIGHTS.

	Pounds.
Carriage No. 3, including tools, but not implements	1,310
Carriage No. 1, including tools, but not implements	1,160
Carriage No. 2	Same as No. 3.
Carriage No. 4	1,237
Carriage No. 5, including tools, but not implements	1,280
Carriage No. 6, including tools, but not implements	1,214
One wheel	200
Pressure of trail on ground, piece unlimbered, carriage No. 3	187
Pressure of trail on pintle-hook, piece limbered, carriage No. 3	140
Pressure of trail on ground, piece unlimbered, carriage No. 1	199
Pressure of trail on pintle-hook, piece limbered, carriage No. 1	147

DISPOSITION MADE OF CARRIAGES.

No. 1. Sent to United States Military Academy, West Point, N. Y.

No. 2. Sent to United States Artillery School, Fort Monroe, Va.

Nos. 3 and 4. Issued to Light Battery F, Fifth United States Artillery, Fort Hamilton, New York Harbor.

Nos. 5 and 6. Sent to Benicia Arsenal, California, for use of Light Battery K, First United States Artillery.

As bearing upon a gun-carriage for the field service, the following is quoted from the proceedings of the Board of Light Artillery Officers convened by virtue of General Orders, No. 39, Headquarters of the Army, A. G. O., Washington, April 28, 1881:

> That the new carriages be of the general form of those now in service, and capable of sustaining the shock of the heavy powder charges proposed without loss of requisite lightness and mobility. To secure these objects the Board is of opinion that the carriage should be made of steel, and in two parts; that part immediately sustaining the gun to have a small movement checked by an elastic buffer, so that the first shock of the recoil may be absorbed before any severe strain comes upon the axle. The carriage to be provided with axle-tree seats facing towards the muzzle, and a double brake for each, while arranged so as not to interfere with the service of the piece, and which can be operated by the cannoneers on the axle-tree seats, and used on the march, in addition to checking the recoil when the gun is fired.
>
> The checks and elevating apparatus to be placed so as to admit of curved fire with reduced charges; the angle of depression to be about 6°, and the height of the axis of the trunnions above the ground to be about the same as in the present carriage.
>
> The elevating-screw to be single, having a slot and a side screw, in order to lock it and prevent it from running down when the gun is fired.
>
> The wheels to be of the Archibald pattern, with eight fellies and sixteen spokes; their height, track, dish, and width of tire to be the same as those of the wheels now in use.
>
> The trail handspike to be of hollow metal, and attached to the trail so that it can be folded on the stock, and be held in place when the gun is fired, and also when the carriage is limbered. There should be a trail-box for implements and a small can of sperm oil on the trail between the cheeks.

These carriages have been submitted for trial in service, not as perfect in plan or construction, but as suitable for use with the breech-loading guns, and as an advance upon the wooden carriage.

Of the minor features, some will doubtless need to be modified, and changes may even be required in the principal parts. These will be developed by trial and by the experience of our Army officers.

Some objectionable points in construction noticed during fabrication were allowed to remain, as their alteration would have delayed, possibly unnecessarily, the completion of the work.

The cost of the carriages was:

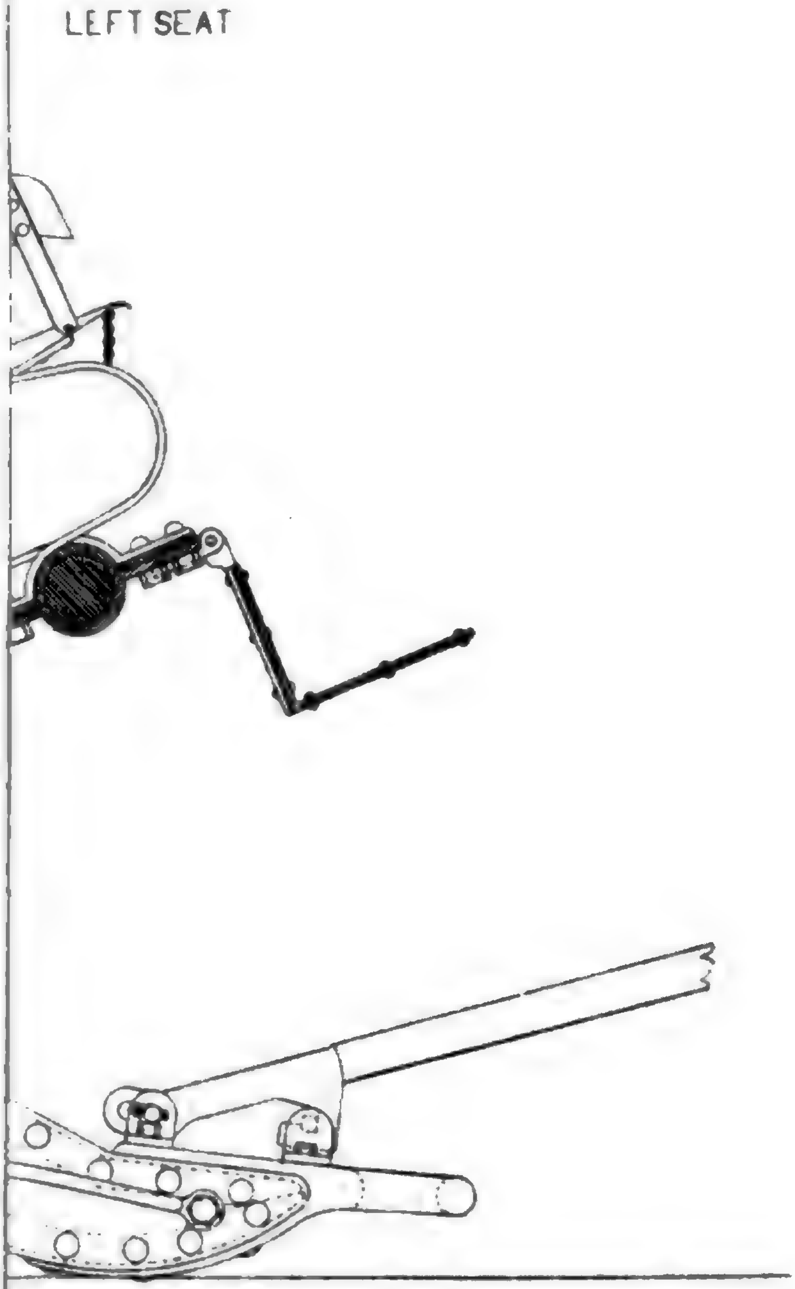
One with axle-seats	$984 64
One without axle-seats	902 64

These figures include the outlay for dies for axle-plates, and for special tools, which increased the cost of each carriage by at least $50.

A. MORDECAI,
Lieutenant-Colonel of Ordnance, commanding.

PLATE I.

IFLE



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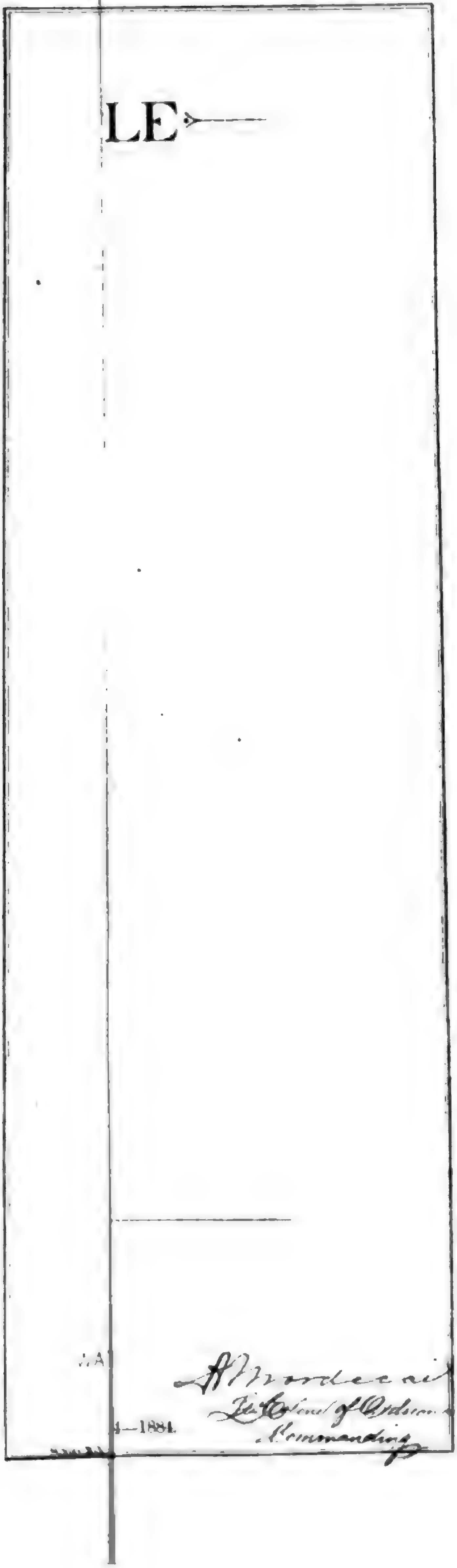
Appendix 34—1884.

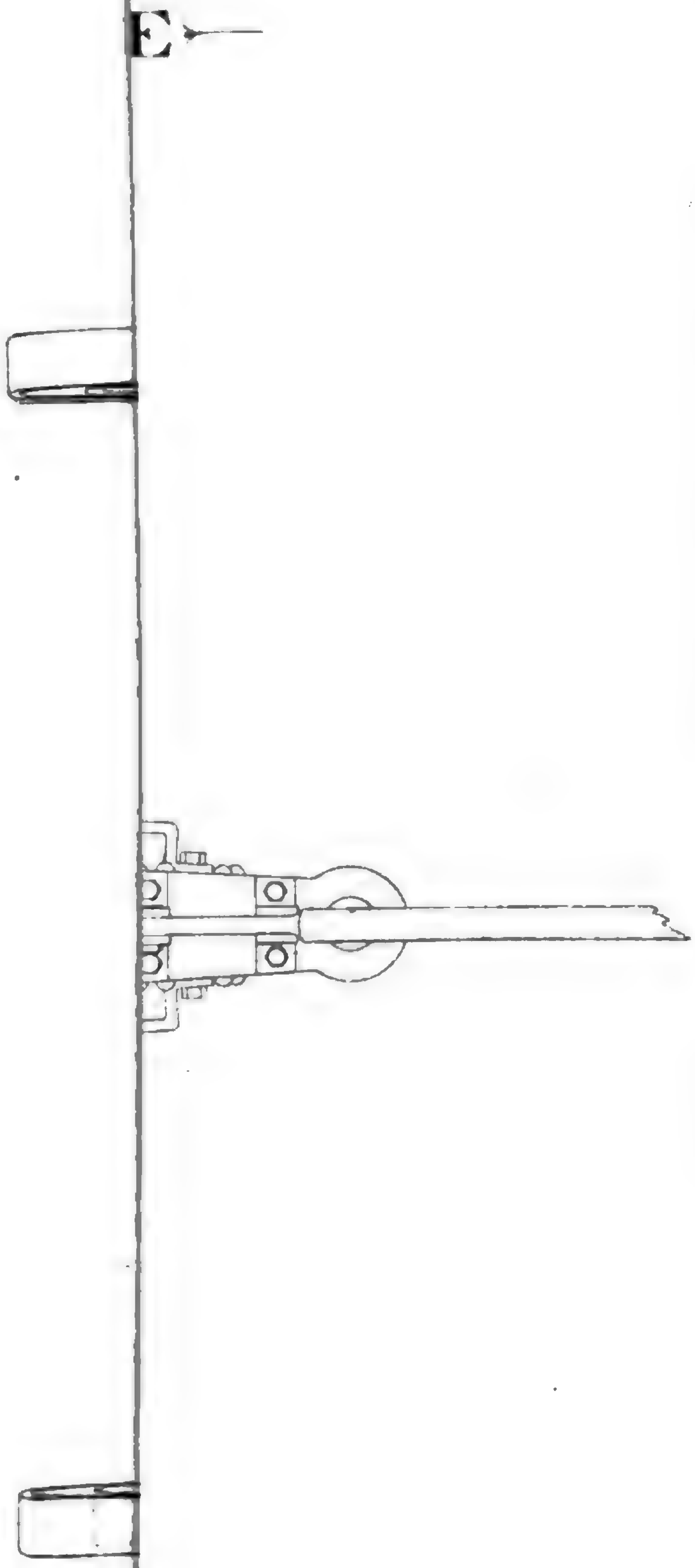
A Mordecai
Lieut. Colonel of Ordnance
Commanding

PLATE II.



A Mordecai
Lt Colonel of Ordnance
Commanding

PLATE III.



WATERVLIET

AUG

ppendix 34—1884

A Mordecai
Lieut. Colonel of Ordnance
Commanding

APPENDIX 35.

DESCRIPTION OF THE PIPER FIELD AND SIEGE GIN.

BY LIEUT. COL. A. MORDECAI, ORDNANCE DEPARTMENT.

(5 plates.)

WATERVLIET ARSENAL,
West Troy, N. Y., July 14, 1884.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

SIR: In accordance with your instructions of January 16, 1884, I have the honor to submit the following description, with plates, of the "Piper gin," for field and siege services, manufactured at this arsenal pursuant to your directions of March 20, 1883.

DESCRIPTION.

This gin consists of—

WOODEN PARTS.

2 legs of spruce.
1 pry-pole of spruce.
2 cleats of oak for pry-pole, fastened by 4 nails.
1 windlass of oak.

And for service of the gin:

2 handspikes of hickory.
3 shoes of two thicknesses of ash plank, fastened by 4 rivets.

METAL PARTS, WROUGHT IRON.

Attached to right leg:
    1 journal-box.
    2 journal-box bolts.
    1 journal-box key; 1 eye-pin and 1 chain for key.
    2 journal-box straps and 2 strap-keys.
    1 pawl, held by 1 bolt screwed into leg.
    1 lower band.
    1 point, and 1 washer, fastened by 3 nails.
    1 lower brace-band, fastened by 3 screws.
    1 upper brace-band, fastened by 4 screws.
    1 lower brace, fastened by nut to stud forming part of the brace-band.
    1 upper band, fastened by 2 screws.
    1 key for clevis-bolt; 1 eye-pin and 1 chain for key.

The metal parts attached to the left leg are similar to those of the right leg, substituting 1 upper brace for the lower brace and adding 1 strap with stud and nut for securing upper brace, fastened by 1 pin and 2 screws.

Attached to the pry-pole:
- 1 lower band.
- 1 point, and 1 washer, fastened by 3 nails.
- 1 band with eye for safety-chain, fastened by 4 screws.
- 1 safety-chain.
- 1 upper band.
- 1 clevis.
- 1 clevis bolt, fastened by 1 pin.

Attached to the windlass:
- 2 gudgeons, fastened by 2 pins.
- 2 handspike sockets (of brass); 2 pawls; 2 springs, held in place by 2 plates each fastened to socket by 3 screws.
- 2 ratchet-wheels.
- 2 bands, fastened each by 3 screws.

The general construction is the same as that of the garrison and casemate gins made by the Ordnance Department, the principal changes being in the journal-boxes and brace-bands, and in the addition of the safety-chain. This last is attached at its middle to the pry-pole, and has one end hooked to each leg, thus preventing the gin from spreading and falling to the ground.

In the fabrication of this gin a mistake was made in the position of the journal-boxes, they being too high for working the windlass advantageously.

It would be better were the axis of the windlass 32 inches from a straight line, joining the inner bottom edges of lower bands on legs, instead of 38½ inches, as made. This would necessitate an increase in the length of the wooden part of windlass, which, in my opinion, would be better than using the same length of windlass and bringing the legs nearer together. The position of the cylindrical part of the legs would have to be changed accordingly, but no other modification would be needed.

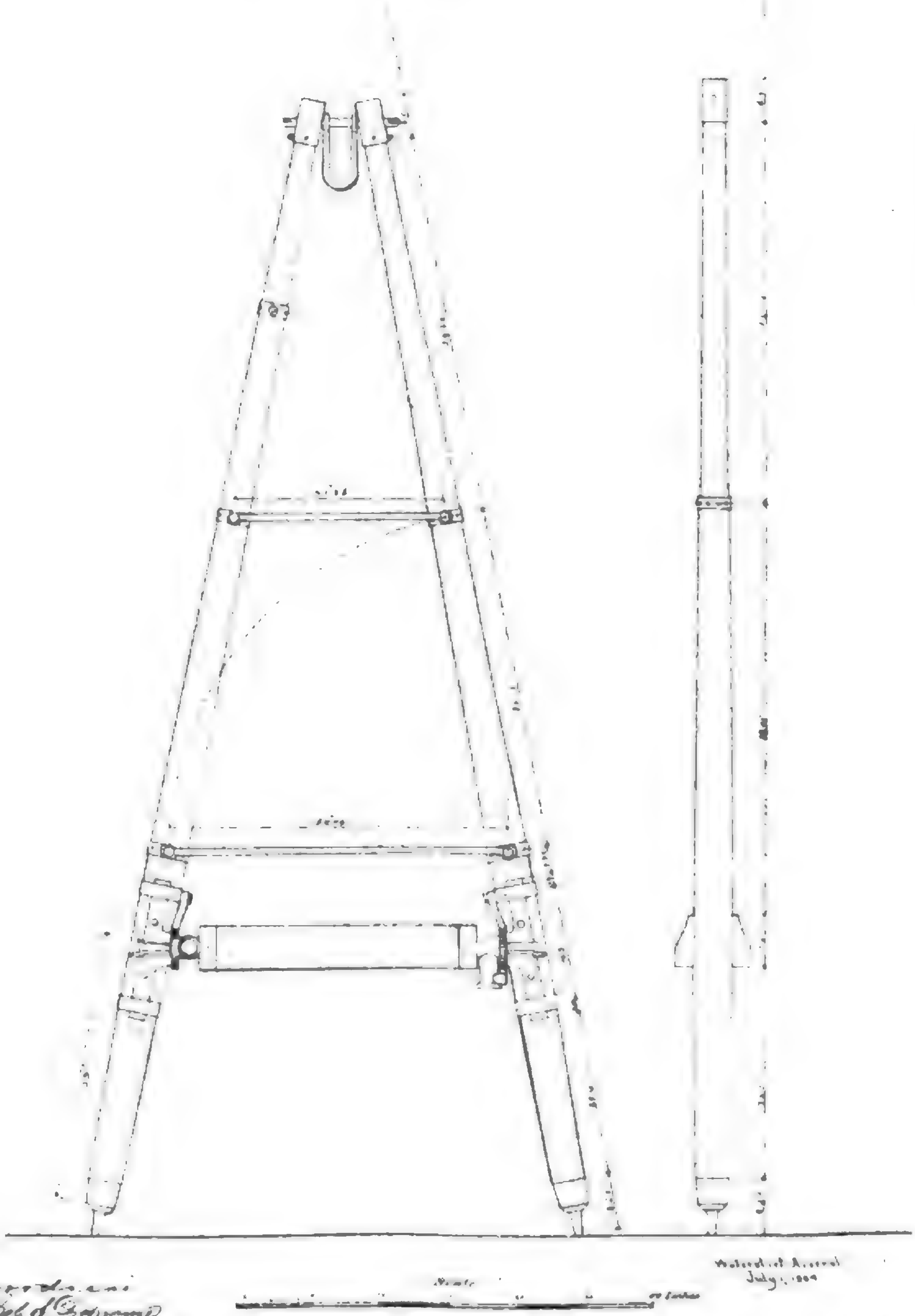
With this gin are used 1 double and 1 single block. The latter is composed of 2 side-plates, the ends bent over the cross-heads; 2 cross-heads; 2 eyes riveted in the cross-heads, and 4 nuts; 1 hook, 1 sheave (of brass), 1 sheave-bolt, and 1 nut.

The double block has, in addition to the above, 1 partition and 1 sheave; it has but 1 eye, riveted in 1 cross-head; the eye in the other is omitted and instead 1 washer with eye and ring is attached by the sheave-bolt to one side of the block.

The photographs that accompanied your letter ordering the fabrication were the main guides by which the gin was made, and any deviations from what was there shown were accidental, except the substitution of two bolts in each journal-box in place of the two dowels shown in the photograph.

The accompanying plates, five in number, show the details of construction and the dimensions of all the parts.

FIELD & SIEGE GIN. PIPER PATTERN.

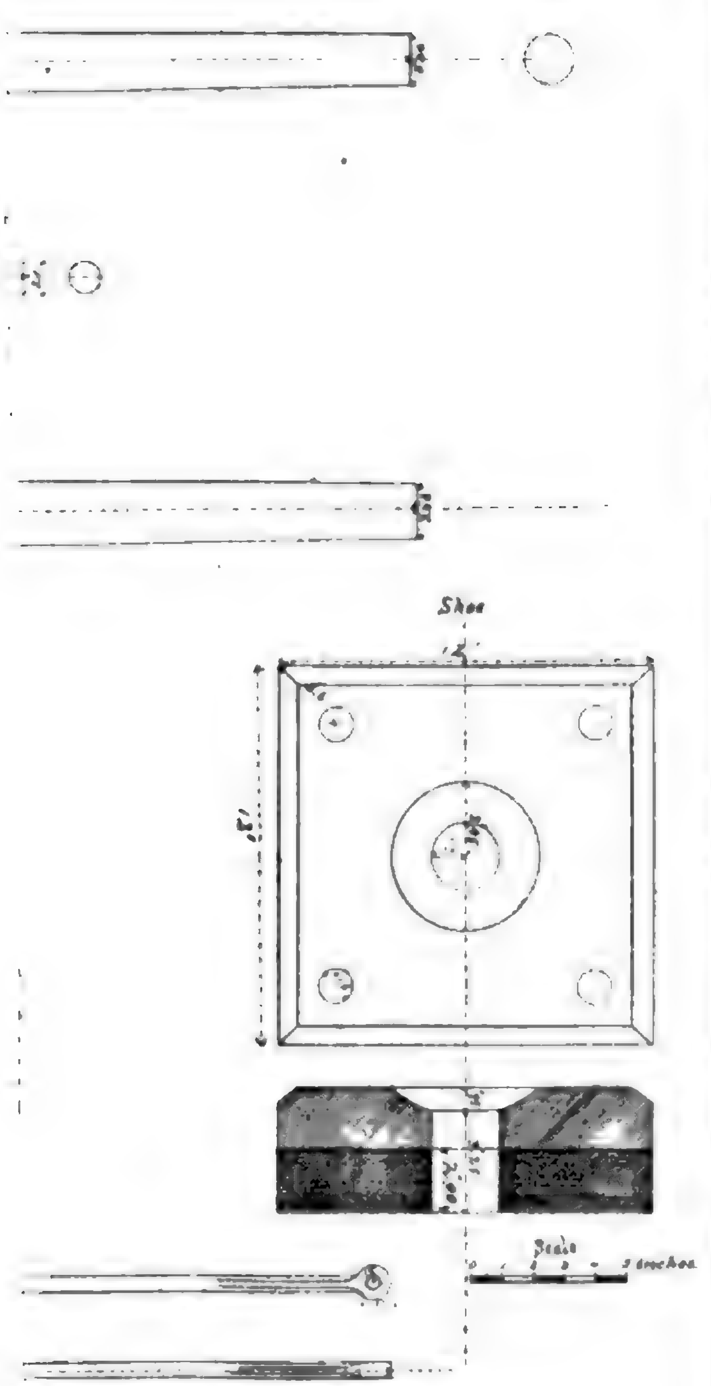


Watervliet Arsenal
July 1, 1904

A Mordecai
Lt Col of Ordnance
Commanding.

Appendix 33—1904

PLATE II.

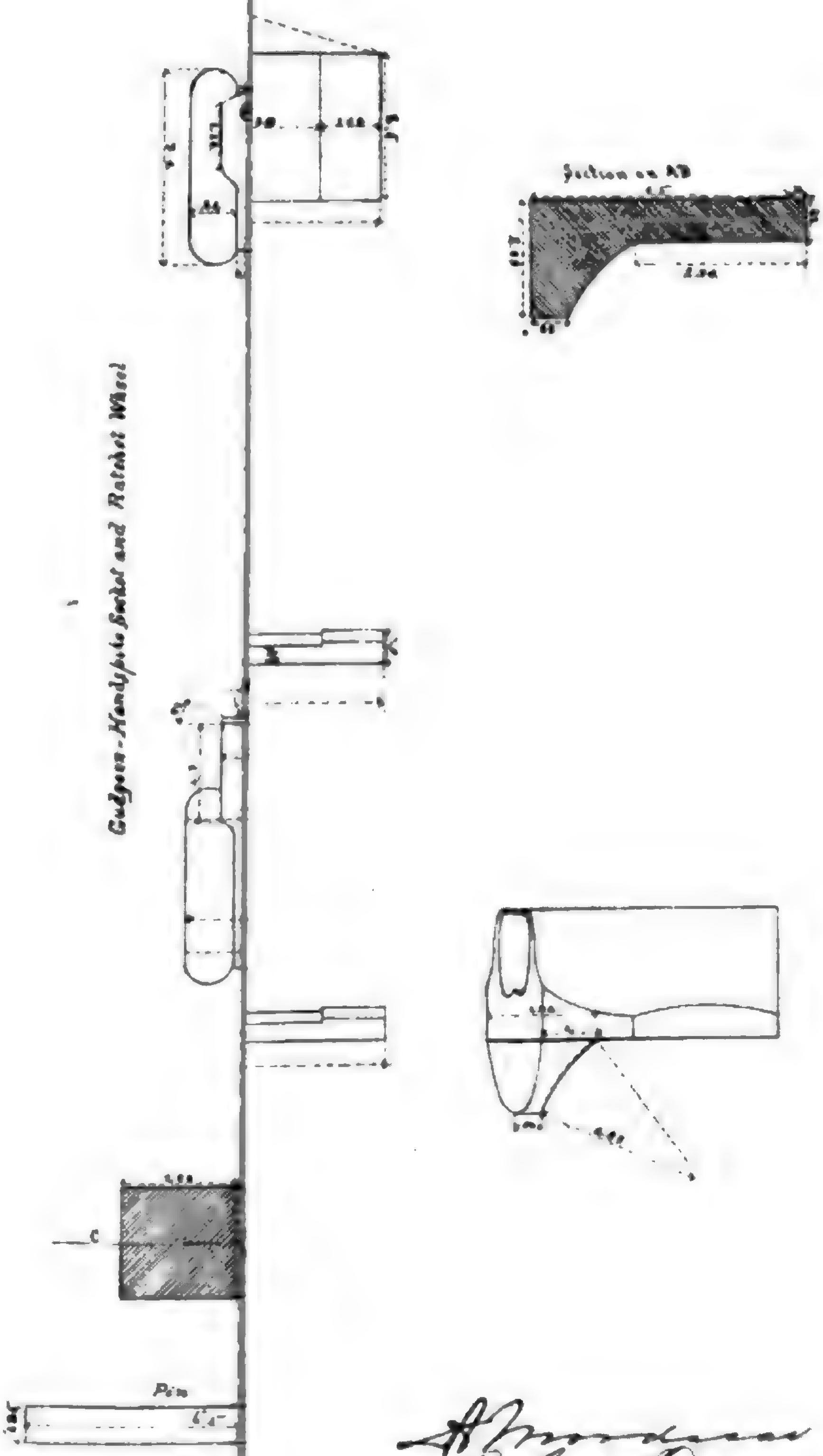


A. Mordecai
Lt. Col. of Ordnance
Comdg

Watervliet Arsenal
July 1, 1884

Appendix 33—1884.

PLATE III.



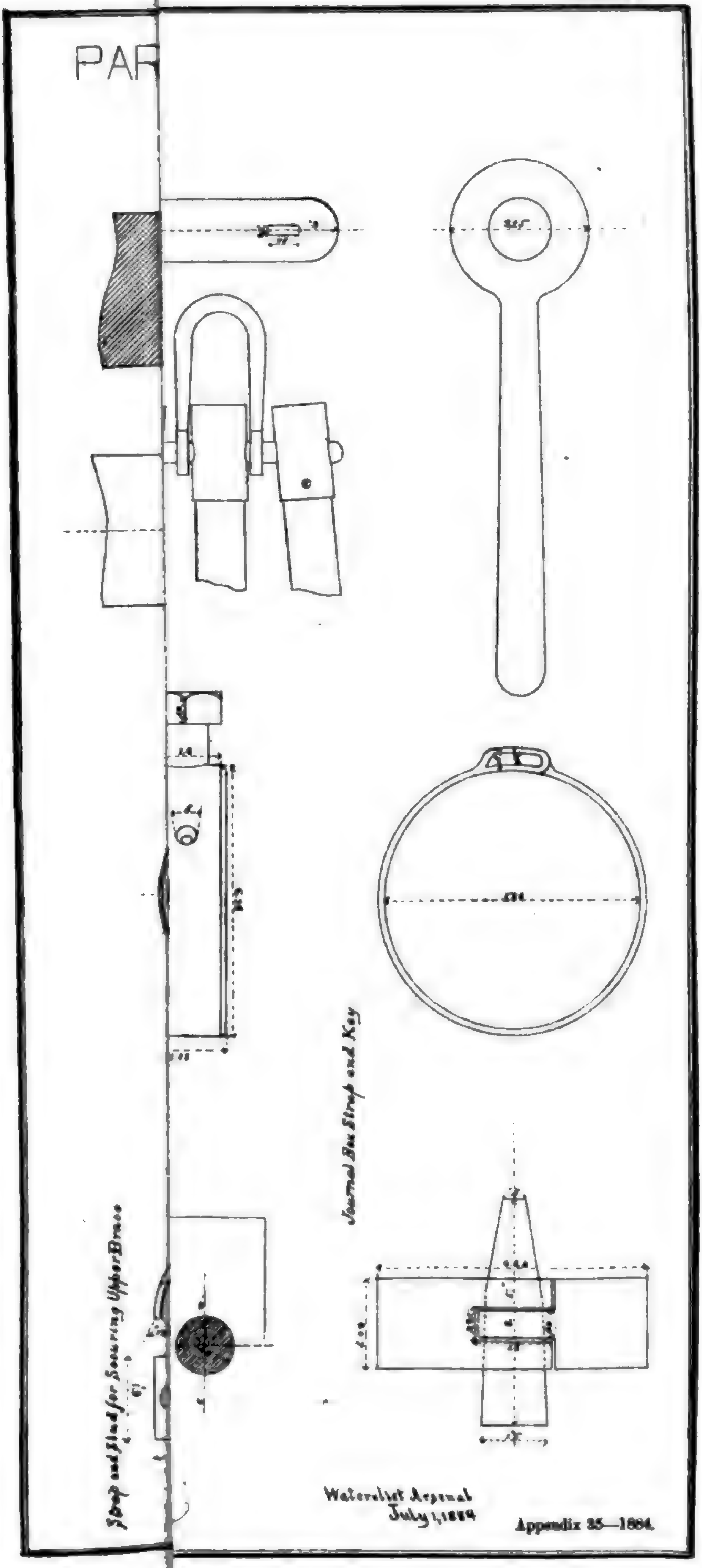
Gudgeon–Handspike Socket and Ratchet Wheel

Lt Col of Ordnance,
Commanding

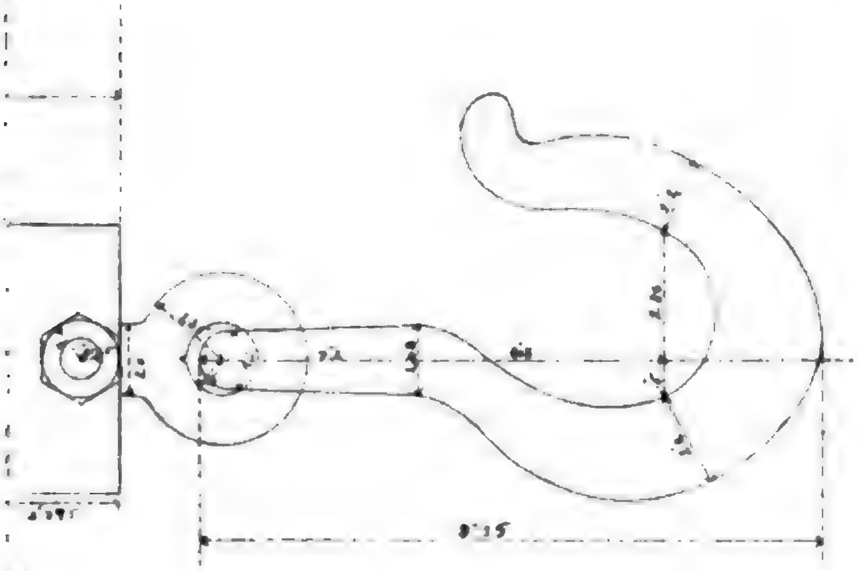
Watervliet Arsenal
July 1, 1884

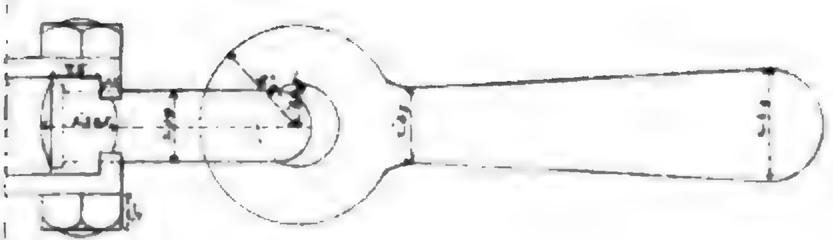
Appendix 25—1884.

PLATE IV.


PAR
Journal Box Strap and Key
Strap and Stud for Securing Upper Brace
Watervliet Arsenal
July 1, 1884

Appendix 35—1884.





Watervliet Arsenal
July 1, 1884

A Mordecai
Lt. Col. of Ordnance,
Comdg.

APPENDIX 36.

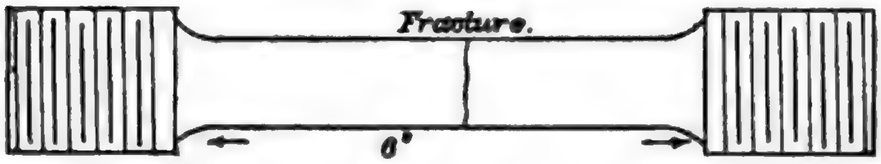
TESTS OF WHITWORTH STEEL FOR 8-INCH BREECH-LOADING RIFLE AND 12-INCH RIFLED MORTAR.

REPORT OF MECHANICAL TESTS, MADE WITH THE UNITED STATES TESTING MACHINE, CAPACITY 800,000 POUNDS, AT WATERTOWN ARSENAL, MASSACHUSETTS, FOR THE ORDNANCE DEPARTMENT, U. S. ARMY, WASHINGTON, D. C.

TESTS BY TENSION: THREE BARS STEEL FROM TRUNNION HOOP 12-INCH MORTAR; THREE BARS STEEL FROM TRUNNION HOOP 8-INCH RIFLE.

July 18, 1884.

No. 317.



[Marks on bar, 12 IN. M. 1972; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000167	.000167	.000050	.000050	
2, 500	10, 000	.000500	.000333	.000267	.000217	
3, 750	15, 000	.000650	.000150	.000267	.000000	
5, 000	20, 000	.000850	.000200	.000317	.000050	
6, 250	25, 000	.001133	.000283	.000400	.000083	
7, 500	30, 000	.001483	.000350	.000566	.000166	
7, 750	31, 000	.001518	.000035	....	....	
8, 000	32, 000	.001550	.000032	....	....	
8, 250	33, 000	.001600	.000050	....	....	
8, 500	34, 000	.001716	.000116	....	....	
8, 750	35, 000	.001783	.000067	.000750	.000184	
9, 000	36, 000	.001883	.000100	....	....	
9, 250	37, 000	.001950	.000067	....	....	
9, 500	38, 000	.002033	.000087	....	....	
9, 750	39, 000	.002150	.000117	....	....	
10, 000	40, 000	.002200	.000050	.000983	.000233	
10, 250	41, 000	.002333	.000133	....	....	
10, 500	42, 000	.002466	.000133	....	....	
10, 750	43, 000	.002533	.000067	....	....	Probable elastic limit.
11, 000	44, 000	.002650	.000117	....	....	
11, 250	45, 000	.002866	.000216	.001433	.000450	
11, 500	46, 000	.003016	.000150	....	....	
11, 750	47, 000	.003200	.000184	....	....	
12, 000	48, 000	.003500	.000300	....	....	
12, 250	49, 000	.003683	.000183	....	....	
12, 500	50, 000	.004066	.000383	.002383	.000950	
12, 750	51, 000	.004316	.000250	....	....	

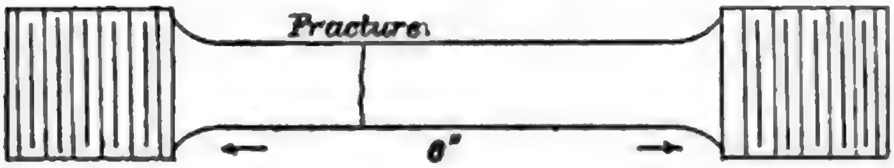
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
13, 000	52, 000	. 004666	. 000350	....	....	
13, 250	53, 000	. 004933	. 000267	....	....	
13, 500	54, 000	. 005633	. 000700	....	....	
13, 750	55, 000	. 006016	. 000383	. 004066	. 001683	
14, 000	56, 000	. 006550	. 000534	....	....	
14, 250	57, 000	. 006916	. 000366	....	....	
14, 500	58, 000	. 007983	. 001067	....	....	
14, 750	59, 000	. 008566	. 000583	....	....	
15, 000	60, 000	. 009466	. 000900	. 007183	. 003117	
15, 250	61, 000	. 009866	. 000400	....	....	
15, 500	62, 000	. 010900	. 001034	....	....	
15, 750	63, 000	. 011366	. 000466	....	....	
16, 000	64, 000	. 012516	. 001150	....	....	
16, 250	65, 000	. 013400	. 000884	. 010916	. 003733	
16, 500	66, 000	. 014450	. 001050	....	....	
16, 750	67, 000	. 015150	. 000700	....	....	
17, 000	68, 000	. 016633	. 001483	....	....	
17, 250	69, 000	. 017833	. 001200	....	....	
17, 300	70, 000	. 019533	. 001700	. 016683	. 005767	
18, 000	72, 000	. 020883	. 001350	....	....	
18, 500	74, 000	. 024066	. 003183	....	....	
19, 000	76, 000	. 026233	. 002167	....	....	
19, 500	78, 000	. 030066	. 003833	....	....	
20, 000	80, 000	. 033500	. 003434	....	....	Micrometer removed.
20, 500	82, 000	. 0417	. 0082	....	....	
21, 000	84, 000	. 0450	. 0033	....	....	
21, 500	86, 000	, 0500	. 0050	....	....	
22, 000	88, 000	. 0583	. 0083	....	....	
22, 500	90, 000	. 0658	. 0075	....	....	
23, 000	92, 000	. 0783	. 0125	....	....	
23, 500	94, 000	. 0983	. 0200	....	....	
23, 680	94, 720	. 1183	. 0200	....	....	Ultimate strength.
....	....	. 1400	. 1217	....	....	
20, 450	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		7. 8636
Hardness		21. 65
Tensile strength per square inch of original section	pounds..	94, 720
Elastic limit	not well defined.	
Elongation per inch after rupture	inch..	. 1750
Elongation per inch under strain of elastic limit		
Reduction in diameter at point of rupture	inch..	. 154
Reduction in area after rupture, per centum of original section		47. 2
Position of rupture	one-fourth inch from middle of stem.	
Character of broken surface	fine, silky, cup-shaped ends.	

Elongation of inch sections: .09 inch, .15 inch, .18 inch (.37 inch fractured section), .16 inch, 10 inch

No. 318.



[Marks on bar, 12 IN. M. 1872.; diameter, .564 inch; sectional area, .25 square inch.]

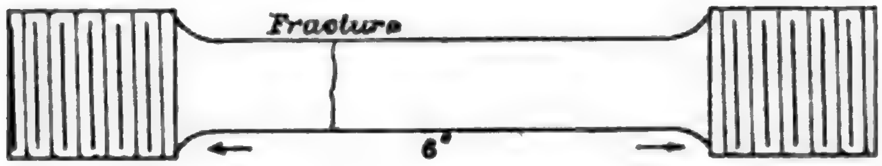
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000116	.000116	0.	0.	
2, 500	10, 000	.000283	.000167	0.	0.	
3, 750	15, 000	.000433	.000150	0.	0.	
5, 000	20, 000	.000600	.000167	.000016	.000016	
6, 250	25, 000	.000816	.000216	.000116	.000100	
6, 500	26, 000	.000866	.000050	....	....	
6, 750	27, 000	.000900	.000034	....	....	
7, 000	28, 000	.000982	.000083	....	....	
7, 250	29, 000	.000983	.000000	....	....	
7, 500	30, 000	.001016	.000033	.000133	.000017	
7, 750	31, 000	.001066	.000050	....	....	
8, 000	32, 000	.001150	.000084	....	....	
8, 250	33, 000	.001183	.000033	....	....	
8, 500	34, 000	.001233	.000050	....	....	
8, 750	35, 000	.001283	.000050	.000200	.000067	
9, 000	36, 000	.001333	.000050	....	....	
9, 250	37, 000	.001350	.000017	....	....	
9, 500	28, 000	.001450	.000100	....	....	
9, 750	39, 000	.001500	.000050	....	....	
10, 000	40, 000	.001533	.000033	.000316	.000116	
10, 250	41, 000	.001633	.000100	....	....	
10, 500	42, 000	.001666	.000033	....	....	
10, 750	43, 000	.001716	.000050	....	....	
11, 000	44, 000	.001783	.000067	....	....	
11, 250	45, 000	.001833	.000050	.000450	.000134	
11, 500	46, 000	.001916	.000083	....	....	
11, 750	47, 000	.001983	.000067	....	....	
12, 000	48, 000	.002083	.000100	....	....	
12, 250	49, 000	.002150	.000067	....	....	
12, 500	50, 000	.002250	.000100	.000666	.000216	
12, 750	51, 000	.002366	.000116	....	....	
13, 000	52, 000	.002433	.000067	....	....	Elastic limit.
13, 250	53, 000	.002600	.000167	....	....	
13, 500	54, 000	.002816	.000216	....	....	
13, 750	55, 000	.002983	.000167	.001183	.000517	
14, 000	56, 000	.003183	.000200	....	....	
14, 250	57, 000	.003450	.000267	....	....	
14, 500	58, 000	.003783	.000333	....	....	
14, 750	59, 000	.004150	.000373	....	....	
15, 000	60, 000	.004616	.000466	.002933	.001750	
15, 250	61, 000	.005016	.000400	....	....	
15, 500	62, 000	.005783	.000667	....	....	
15, 750	63, 000	.006283	.000500	....	....	
16, 000	64, 000	.007033	.000750	....	....	
16, 250	65, 000	.007913	.000880	.005550	.002617	
16, 500	66, 000	.008566	.000653	....	....	
16, 750	67, 000	.009316	.000750	....	....	
17, 000	68, 000	.010466	.001050	....	....	
17, 250	69, 000	.011250	.000784	....	....	
17, 500	70, 000	.012483	.001233	.009813	.004263	
18, 000	72, 000	.013883	.001400	....	....	
18, 500	74, 000	.016050	.002167	....	....	
19, 000	76, 000	.018383	.002333	....	....	
19, 500	78, 000	.020733	.002350	....	....	
20, 000	80, 000	.023333	.002600	....	....	
20, 500	82, 000	.026083	.002750	....	....	
21, 000	84, 000	.029083	.003000	....	....	
21, 500	86, 000	.032483	.003400	....	....	
22, 000	88, 000	.036333	.003850	....	....	
22, 500	90, 000	.040400	.004067	....	....	Micrometer removed.
23, 000	92, 000	.0450	.0046	....	....	
23, 500	94, 000	.0517	.0067	....	....	
24, 000	96, 000	.0613	.0096	....	....	
24, 500	98, 000	.0717	.0104	....	....	
25, 000	100, 000	.0900	.0183	....	....	
25, 140	100, 560	.1083	.0183	....	....	Ultimate strength.
22, 600	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity ....
Hardness ....
Tensile strength per square inch of original section ....pounds.. 100, 560
Elastic limit per square inch of original section ....do.... 52, 000
Elongation per inch after rupture ....inch.. .1433
Elongation per inch under strain at elastic limit ....do.... .002433
Reduction in diameter at point of rupture ....do.... .124
Reduction in area after rupture, per centum of original section 39.2
Position of rupture ....2 inches from neck.
Character of broken surface.......dull, spongy center, 60 per cent.; fine granular at circumference, 40 per cent.

Elongation of inch sections: .09 inch (.29 inch fractured section), .14 inch, .15 inch, 11 inch, .08 inch.

No. 319.



[Marks on bar, 12 IN. M. 1972.; diameter, .564 inches; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.	....	
2, 500	10, 000	.000217	.000134	0.	....	
3, 750	15, 000	.000350	.000133	—.000066	.000066	
5, 000	20, 000	.000516	.000166	—.000066	.000000	
6, 250	25, 000	.000783	.000217	.000033	.000099	
6, 500	26, 000	.000766	.000033	....	....	
6, 750	27, 000	.000833	.000067	....	....	
7, 000	28, 000	.000883	.000050	....	....	
7, 250	29, 000	.000916	.000033	....	....	
7, 500	30, 000	.000950	.000034	.000100	.000067	
7, 750	31, 000	.000966	.000016	....	....	
8, 000	32, 000	.001033	.000067	....	....	
8, 250	33, 000	.001083	.000050	....	....	
8, 500	34, 000	.001150	.000067	....	....	
8, 750	35, 000	.001233	.000083	.000166	.000066	
9, 000	36, 000	.001283	.000050	....	....	
9, 250	37, 000	.001316	.000033	....	....	
9, 500	38, 000	.001400	.000084	....	....	
9, 750	39, 000	.001416	.000016	....	....	
10, 000	40, 000	.001516	.000100	.000266	.000100	
10, 250	41, 000	.001566	.000050	....	....	
10, 500	42, 000	.001616	.000050	....	....	
10, 750	43, 000	.001700	.000084	....	....	
11, 000	44, 000	.001766	.000066	....	....	
11, 250	45, 000	.001800	.000034	.000416	.000150	
11, 500	46, 000	.001900	.000100	....	....	
11, 750	47, 000	.001966	.000066	....	....	
12, 000	48, 000	.002116	.000150	....	....	
12, 250	49, 000	.002183	.000067	....	....	Probable elastic limit.
12, 500	50, 000	.002283	.000100	.000716	.000300	
12, 750	51, 000	.002416	.000133	....	....	
13, 000	52, 000	.002583	.000167	....	....	
13, 250	53, 000	.002700	.000117	....	....	
13, 500	54, 000	.002983	.000283	....	....	
13, 750	55, 000	.003183	.000200	.001416	.000700	
14, 000	56, 000	.003483	.000300	....	....	
14, 250	57, 000	.003716	.000233	....	....	
14, 500	58, 000	.004283	.000567	....	....	
14, 750	59, 000	.004800	.000517	....	....	
15, 000	60, 000	.005516	.000716	.003416	.002000	
15, 250	61, 000	.005783	.000267	....	....	
15, 500	62, 000	.006633	.000850	....	....	
15, 750	63, 000	.007233	.000600	....	....	
16, 000	64, 000	.008133	.000900	....	....	

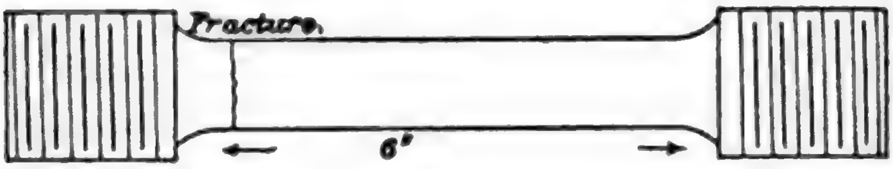
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
16, 250	65, 000	.008983	.000750	.006583	.003167	
16, 500	66, 000	.009766	.000783	....	....	
16, 750	67, 000	.010583	.000817	....	....	
17, 000	68, 000	.011583	.001000	....	....	
17, 250	69, 000	.012350	.000767	....	....	
17, 500	70, 000	.013750	.001400	.011833	.005250	
18, 000	72, 000	.015383	.001633	....	....	
18, 500	74, 000	.017716	.001333	....	....	
19, 000	76, 000	.020283	.062567	....	....	
19, 500	78, 000	.022600	.002317	....	....	
20, 000	80, 000	.025316	.002716	....	....	
20, 500	82, 000	.028333	.003017	....	....	
21, 000	84, 000	.031716	.003383	....	....	
21, 500	86, 000	.035333	.003617	....	....	
22, 000	88, 000	.038833	.003500	....	....	
22, 500	90, 000	.043583	.004750	....	....	Micrometer removed.
23, 000	92, 000	.0500	.0065	....	....	
23, 500	94, 000	.0583	.0083	....	....	
24, 000	96, 000	.0717	.0134	....	....	
24, 250	97, 000	.0817	.0100	....	....	
24, 500	98, 000	{ .0917 { .1017	.0100 .0100	....	....	Ultimate strength.
21, 380	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity ....
Hardness ....
Tensile strength per square inch of original section ....pounds.. 98, 000
Elastic limit per square inch of original section ....not well defined.
Elongation per inch after rupture ....inch.. .135
Elongation per inch under strain at elastic limit ....
Reduction in diameter at point of rupture ....inch.. .144
Reduction in area after rupture, per centum of original section 44. 6
Position of rupture ....1.85 inches from neck.
Character of broken surface..dull, smoky center, 60 per cent.; fine granular at circumference, 40 per cent.

Elongation of inch sections: .05 inch, .07 inch, .10 inch, .13 inch (.34 inch fractured section), .12 inch.

No. 332.



[Marks on bar, $\frac{8 \text{ I N. R.}}{1972}$; diameter .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.	....	
2, 500	10, 000	.000233	.000150	0.	....	
3, 750	15, 000	.000383	.000150	0.	....	
5, 000	20, 000	.000550	.000167	0.	....	
6, 250	25, 000	.000800	.000250	.000116	.000116	
6, 500	26, 000	.000833	.000033	....	....	
6, 750	27, 000	000883	.000050	....	....	

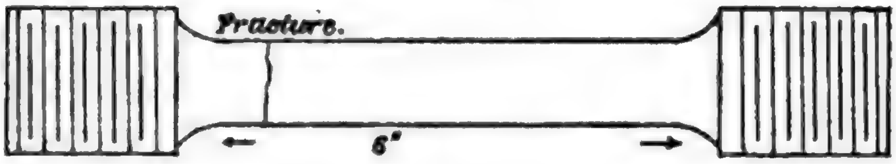
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
7, 000	28, 000	. 000966	. 000083	....	....	
7, 250	29, 000	. 001050	. 000084	....	....	
7, 500	30, 000	. 001100	. 000050	. 000233	. 000117	
7, 750	31, 000	. 001166	. 000066	....	....	
8, 000	32, 000	. 001233	. 000067	....	....	
8, 250	33, 000	. 001300	. 000067	....	....	
8, 500	34, 000	. 001400	. 000100	....	....	
8, 750	35, 000	. 001433	. 000033	. 000416	. 000183	
9, 000	36, 000	. 001483	. 000050	....	....	
9, 250	37, 000	. 001550	. 000067	....	....	
9, 500	38, 000	. 001650	. 000100	....	....	
9, 750	39, 000	. 001716	. 000066	....	....	Probable elastic limit.
10, 000	40, 000	. 001866	. 000150	. 000600	. 000184	
10, 250	41, 000	. 001966	. 000100	....	....	
10, 500	42, 000	. 002066	. 000100	....	....	
10, 750	43, 000	. 002166	. 000100	....	....	
11, 000	44, 000	. 002400	. 000234	....	....	
11, 250	45, 000	. 002600	. 000200	. 001150	. 000550	
11, 500	46, 000	. 002866	. 000266	....	....	
11, 750	47, 000	. 003066	. 000200	....	....	
12, 000	48, 000	. 003533	. 000467	....	....	
12, 250	49, 000	. 003983	. 000450	....	....	
12, 500	50, 000	. 004750	. 000767	. 003016	. 001866	
12, 750	51, 000	. 005033	. 000283	....	....	
13, 000	52, 000	. 005700	. 000667	....	....	
13, 250	53, 000	. 006283	. 000583	....	....	
13, 500	54, 000	. 007000	. 000717	....	....	
13, 750	55, 000	. 007550	. 000550	. 005533	. 002517	
14, 000	56, 000	. 008266	. 000716	....	....	
14, 250	57, 000	. 008900	. 000634	....	....	
14, 500	58, 000	. 009750	. 000850	....	....	
14, 750	59, 000	. 010650	. 000900	....	....	
15, 000	60, 000	. 011716	. 001066	. 009400	. 003867	
15, 500	62, 000	. 013150	. 001434	....	....	
16, 000	64, 000	. 015166	. 002011	....	....	
16, 500	66, 000	. 017866	. 002700	....	....	
17, 000	68, 000	. 020100	. 002234	....	....	
17, 500	70, 000	. 022433	. 002333	....	....	
18, 000	72, 000	. 024883	. 002450	....	....	
18, 500	74, 000	. 027650	. 002787	....	....	
19, 000	76, 000	. 031650	. 004000	....	....	Micrometer removed.
19, 500	78, 000	. 0350	. 0034	....	....	
20, 000	80, 000	. 0383	. 0033	....	....	
20, 500	82, 000	. 0450	. 0067	....	....	
21, 000	84, 000	. 0517	. 0067	....	....	
21, 500	86, 000	. 0583	. 0066	....	....	
22, 000	88, 000	. 0667	. 0084	....	....	
22, 500	90, 000	. 0833	. 0166	....	....	
23, 000	92, 000	. 1150	. 0317	....	....	
23, 030	92, 120	. 1283	. 0133	....	....	Ultimate strength.
19, 100	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity..	
Hardness	
Tensile strength per square inch of original section ....pounds..	92, 120
Elastic limit per square inch of original section............................not well defined.	
Elongation per inch after rupture..inch..	. 1700
Elongation per inch under strain at elastic limit..............................	
Reduction in diameter at point of rupture.....................................inch..	. 174
Reduction in area after rupture, per centum of original section.................	52. 2
Position of rupture..three-fourths inch from neck.	
Character of broken surface..................................fine, silky, cup-shaped ends	

Elongation of inch sections: .07 inch, .11 inch, .11 inch, .14 inch, .18 inch (.41 inch fractured section).

No. 333.



[Marks on bar, $\genfrac{}{}{0pt}{}{\text{8 IN R.}}{1972}$; diameter, .564 inch; sectional area, .25 square inch.]

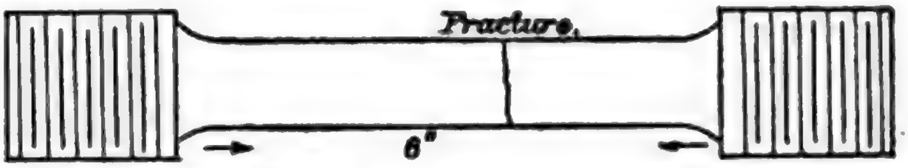
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000083	.000083	0.	....	
2, 500	10, 000	.000250	.000167	0.	....	
3, 750	15, 000	.000416	.000166	0.	....	
5, 000	20, 000	.000533	.000117	0.	....	
5, 250	21, 000	.000566	.000033	....	....	
5, 500	22, 000	.000583	.000017	....	....	
5, 750	23, 000	.000633	.000050	....	....	
6, 000	24, 000	.000683	.000050	....	....	
6, 250	25, 000	.000733	.000050	.000050	.000050	
6, 500	26, 000	.000783	.000050	....	....	
6, 750	27, 000	.000833	.000050	....	....	
7, 000	28, 000	.000883	.000050	....	....	
7, 250	29, 000	.000933	.000050	....	....	
7, 500	30, 000	.001000	.000067	.000150	.000100	
7, 750	31, 000	.001050	.000050	....	....	
8, 000	32, 000	.001133	.000083	....	....	
8, 250	33, 000	.001166	.000033	....	....	
8, 500	34, 000	.001216	.000050	....	....	
8, 750	35, 000	.001316	.000100	.000316	.000166	
9, 000	36, 000	.001366	.000050	....	....	
9, 250	37, 000	.001400	.000034	....	....	
9, 500	38, 000	.001483	.000083	....	....	
9, 750	39, 000	.001566	.000083	....	....	
10, 000	40, 000	.001650	.000084	.000483	.000167	Probable elastic limit.
10, 250	41, 000	.001750	.000100	....	....	
10, 500	42, 000	.001883	.000133	....	....	
10, 750	43, 000	.002000	.000117	....	....	
11, 000	44, 000	.002150	.000150	....	....	
11, 250	45, 000	.002233	.000083	.000850	.000367	
11, 500	46, 000	.002516	.000283	....	....	
11, 750	47, 000	.002683	.000167	....	....	
12, 000	48, 000	.003133	.000450	....	....	
12, 250	49, 000	.003500	.000367	....	....	
12, 500	50, 000	.004566	.001066	.002866	.002016	
12, 750	51, 000	.004850	.000284	....	....	
13, 000	52, 000	.005233	.000383	....	....	
13, 250	53, 000	.006050	.000817	....	....	
13, 500	54, 000	.006566	.000516	....	....	
13, 750	55, 000	.007066	.000500	.005166	.002300	
14, 000	56, 000	.007816	.000750	....	....	
14, 250	57, 000	.008516	.000700	....	....	
14, 500	58, 000	.009466	.000950	....	....	
14, 750	59, 000	.010016	.000550	....	....	
15, 000	60, 000	.011133	.001117	.009066	.003900	
15, 500	62, 000	.013000	.001867	....	....	
16, 000	64, 000	.015500	.002500	....	....	
16, 500	66, 000	.017100	.001600	....	....	
17, 000	68, 000	.019916	.002816	....	....	
17, 500	70, 000	.022366	.002450	....	....	
18, 000	72, 000	.025133	.002767	....	....	
18, 500	74, 000	.027900	.002767	....	....	
19, 000	76, 000	.031400	.003500	....	....	
19, 500	78, 000	.033566	.002166	....	....	
20, 000	80, 000	.039650	.006084	....	....	Micrometer removed.
20, 500	82, 000	.0433	.0037	....	....	
21, 000	84, 000	.0500	.0067	....	....	
21, 500	86, 000	.0583	.0083	....	....	
22, 000	88, 000	.0683	.0100	....	....	
22, 500	90, 000	.0867	.0184	....	....	
22, 990	91, 960	.1300	.0433	....	....	Ultimate strength.
19, 400	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity ....
Hardness ....
Tensile strength per square inch of original section ....pounds.. 91, 960
Elastic limit per square inch of original section ....not well defined.
Elongation per inch after rupture ....inch.. .1783
Elongation per inch under strain at elastic limit ....
Reduction in diameter at point of rupture ....inch.. .174
Reduction in area after rupture, per centum of original section 52.1
Position of rupture ....2¼ inches from middle.
Character of broken surface .... fine silky cup-shaped ends.

Elongation of inch sections: .08 inch, .11 inch, .14 inch, .25 inch (.37 inch fractured section), .12 inch.

No. 334.



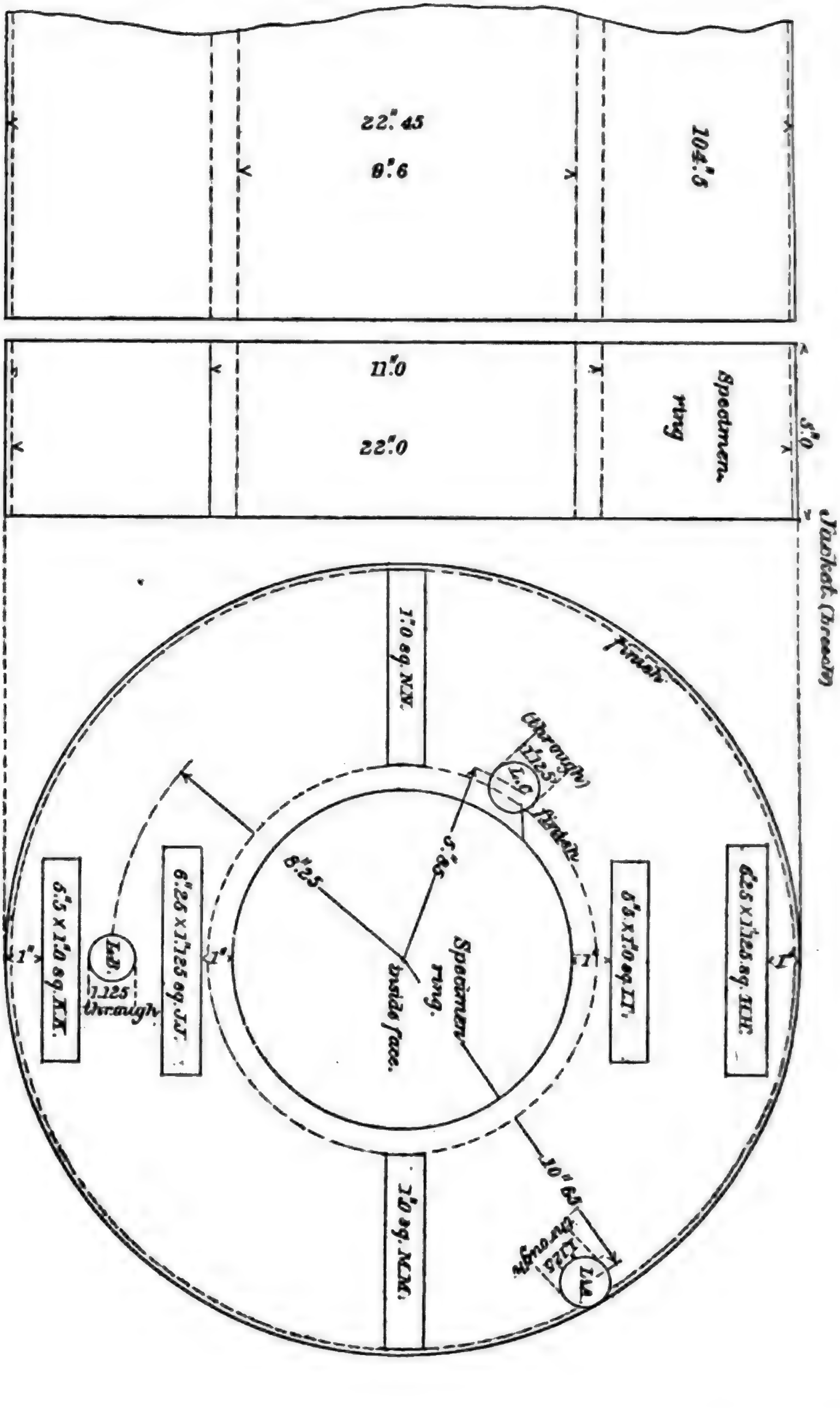
[Marks on bar, 8 I N. R.; 1972; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000116	.000116	0.	....	
2, 500	10, 000	.000283	.000167	0.	....	
3, 750	15, 000	.000416	.000133	0.	....	
5, 000	20, 000	.000583	.000167	.000016	.000016	
5, 250	21, 000	.000600	.000017	....	....	
5, 500	22, 000	.000650	.000050	....	....	
5, 750	23, 000	.000683	.000033	....	....	
6, 000	24, 000	.000766	.000083	....	....	
6, 250	25, 000	.000833	.000067	.000133	.000117	
6, 500	26, 000	.000933	.000100	....	....	
6, 750	27, 000	.001016	.000083	....	....	
7, 000	28, 000	.001100	.000084	....	....	
7, 250	29, 000	.001250	.000050	....	....	
7, 500	30, 000	.001333	.000083	.000466	.000333	Probable elastic limit.
7, 750	31, 000	.001450	.000117	....	....	
8, 000	32, 000	.001633	.000183	....	....	
8, 250	33, 000	.001733	.000100	....	....	
8, 500	34, 000	.001966	.000233	....	....	
8, 750	35, 000	.002133	.000167	.001083	.000617	
9, 000	36, 000	.002466	.000333	....	....	
9, 250	37, 000	.002683	.000217	....	....	
9, 500	38, 000	.003183	.000500	....	....	
9, 750	39, 000	.003633	.000450	....	....	
10, 000	40, 000	.004850	.001217	.003516	.002433	
10, 250	41, 000	.005300	.000450	....	....	
10, 500	42, 000	.005966	.000666	....	....	
10, 750	43, 000	.006633	.000667	....	....	
11, 000	44, 000	.007633	.001000	....	....	
11, 250	45, 000	.008416	.000783	.006833	.003317	
11, 500	46, 000	.009550	.001134	....	....	
11, 750	47, 000	.010483	.000933	....	....	
12, 000	48, 000	.011883	.001400	....	....	
12, 250	49, 000	.012583	.000700	....	....	
12, 500	50, 000	.014050	.001467	.012233	.005400	
12, 750	51, 000	.015066	.001016	....	....	
13, 000	52, 000	.016500	.001434	....	....	
13, 250	53, 000	.017250	.000750	....	....	
13, 500	54, 000	.018916	.001666	....	....	
13, 750	55, 000	.020333	.001417	.018333	.006100	
14, 000	56, 000	.022233	.001900	....	....	
14, 250	57, 000	.023633	.001400	....	....	
14, 500	58, 000	.025400	.001767	....	....	
14, 750	59, 000	.027200	.001800	....	....	
15, 000	60, 000	.029300	.002100	.027016	.008683	
15, 500	62, 000	.033700	.004400	....	....	
16, 000	64, 000	.038233	.004533	....	....	
16, 500	66, 000	.044200	.005967	....	....	
17, 000	68, 000	.051466	.007266	....	....	
17, 5 0	70, 000	.058533	.007067	....	....	Micrometer removed.
18, 000	72, 000	.0733	.0148	....	....	
18, 500	74, 000	.0883	.0150	....	....	
19, 000	76, 000	.1350	.0467	....	....	Ultimate strength.
17, 000	....	....	....	....	....	Load at time of fracture.

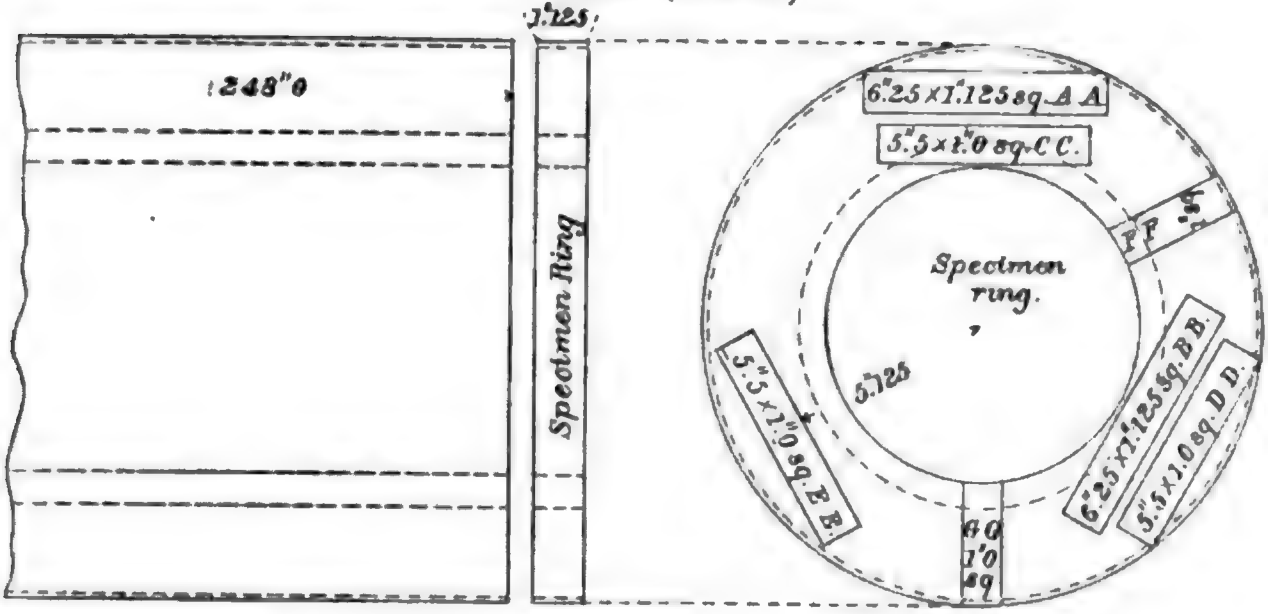
GENERAL SUMMARY.

Specific gravity		7. 8665
Hardness		16. 91
Tensile strength per square inch of original section	pounds	76, 000
Elastic limit per square inch of original section	not well defined.	
Elongation per inch after rupture	inch	. 1733
Elongation per inch under strain of elastic limit		
Reduction in diameter at point of rupture	inch	. 154
Reduction in area after rupture, per centum of original section		47. 2
Position of rupture		.60 inch from middle of stem.
Character of broken surface		dull, silky center, 60 per cent.; fine granular at circumference, 40 per cent.; surface of bar has mottled appearance.

Elongation of inch sections: .15 inch, .20 inch (.43 inch fractured section), .13 inch, .09 inch, .04 inch.

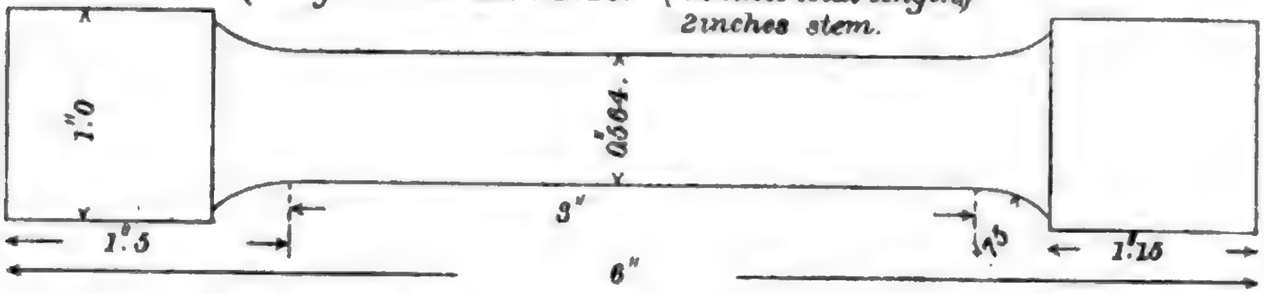

22".45
8".6
104".5
11".0
22".0
Specimen ring
5".0
Jacket (breech)
finish
1".0 sq. N.N.
(through) 1".125
L.G.
finish
5".65
8".25
6".5 x 1".0 sq. K.K.
K.P.
1.125 through
6".25 x 1".125 sq. J.J.
1"
Specimen ring. inside face.
6".5 x 1".0 sq. I.I.
6".25 x 1".125 sq. H.H.
1".0 sq. M.M.
10".65
1.125 through
L.M.

Tube. (breech)

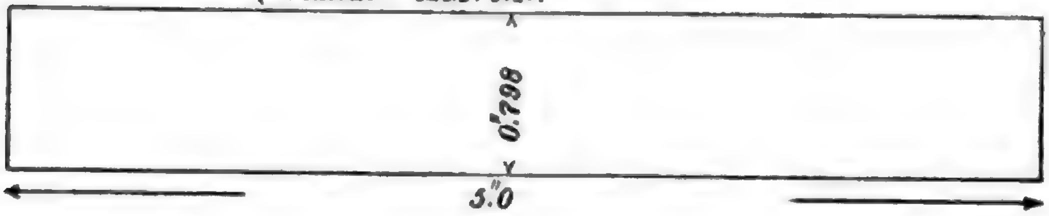


Specimens.

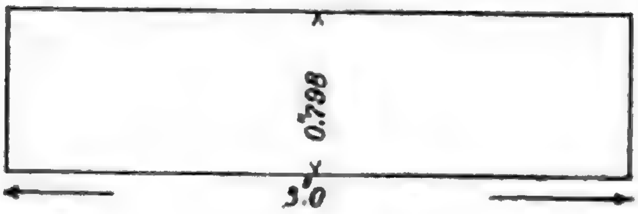
Tensile. { tangential AA. BB. HH. JJ.
longitudinal LA. LB. LC. (5 inches total length,)
2 inches stem.



Compression { tangential CC. DD. EE. II. KK.
radial MM. NN.



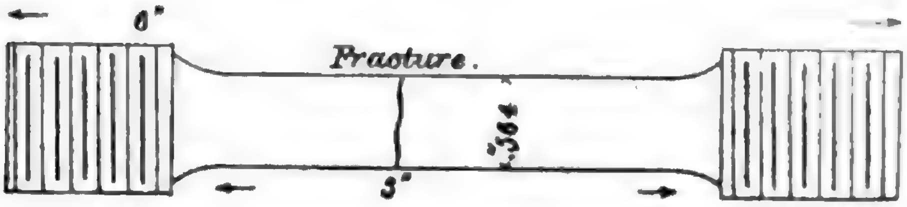
Crushing FF. GG.



TESTS BY TENSION: FIVE SPECIMENS WHITWORTH STEEL FROM JACKET OF 8-INCH BREECH-LOADING RIFLE; TWO SPECIMENS WHITWORTH STEEL FROM TUBE OF 8-INCH BREECH-LOADING RIFLE.

August 5, 1884.

No. 375.



[Marks on bar, A. A.; diameter, .564 inch; sectional area, .25 square inch.]

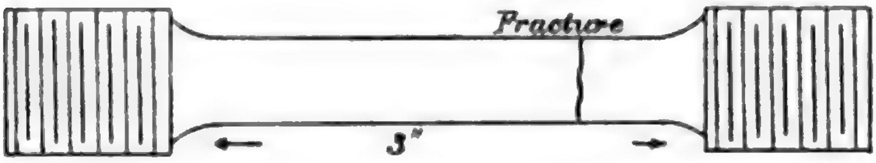
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000067	.000067	0.	....	
2, 500	10, 000	.000233	.000166	0.	....	
3, 750	15, 000	.000400	.000167	0.	....	
5, 000	20, 000	.000567	.000167	0.	....	
6, 250	25, 000	.000733	.000166	0.	....	
7, 500	30, 000	.000933	.000200	.000067	.000067	
7, 750	31, 000	.001000	.000067	....	....	
8, 000	32, 000	.001033	.000033	....	....	
8, 250	33, 000	.001067	.000034	....	....	
8, 500	34, 000	.001200	.000133	....	....	
8, 750	35, 000	.001267	.000067	.000200	.000133	
9, 000	36, 000	.001333	.000066	....	....	
9, 250	37, 000	.001400	.000067	....	....	Elastic limit.
9, 500	38, 000	.001700	.000300	....	....	
9, 750	39, 000	.001900	.000200	....	....	
10, 000	40, 000	.002433	.000533	.001100	.000900	
10, 250	41, 000	.002700	.000267	....	....	
10, 500	42, 000	.003367	.000667	....	....	
10, 750	43, 000	.004133	.000766	....	....	
11, 000	44, 000	.005333	.001200	....	....	
11, 250	45, 000	.005933	.000600	.004267	.003167	
11, 500	46, 000	.006700	.000767	....	....	
11, 750	47, 000	.007533	.000833	....	....	
12, 000	48, 000	.008533	.001000	....	....	
12, 250	49, 000	.009167	.000634	....	....	
12, 500	50, 000	.010500	.001333	.008533	.004266	
13, 000	52, 000	.012000	.001500	....	....	
13, 500	54, 000	.013500	.001500	....	....	
14, 000	56, 000	.015667	.002167	....	....	
14, 500	58, 000	.018200	.002533	....	....	
15, 000	60, 000	.019933	.001733	....	....	
15, 500	62, 000	.022267	.002334	....	....	
16, 000	64, 000	.024993	.002666	....	....	
16, 500	66, 000	.028867	.003934	....	....	
17, 000	68, 000	.031600	.002733	....	....	
17, 500	70, 000	.035400	.003800	....	....	Micrometer removed.
18, 000	72, 000	.0433	.0079	....	....	
18, 500	74, 000	.0500	.0067	....	....	
19, 000	76, 000	.0533	.0033	....	....	
19, 500	78, 000	.0600	.0067	....	....	
20, 000	80, 000	.0700	.0100	....	....	
20, 500	82, 000	.0833	.0133	....	....	
21, 000	84, 000	.0967	.0134	....	....	
21, 500	86, 000	.1300	.0333	....	....	
21, 720	86, 880	.1667	.0367	....	....	Ultimate strength.
21, 100	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	86, 880
Elastic limit per square inch of original section	do....	37, 000
Elongation per inch after rupture	inch..	.02133
Elongation per inch under strain at elastic limit	do....	.001400
Reduction in diameter at point of rupture	do ...	.094
Reduction in area after rupture, per centum of original section		30. 6
Position of rupture		.35 inch from middle of stem.
Character of broken surface		grannlar, 70 per cent.; 30 per cent. of the fracture took an oblique course across the bar, apparently through a seam.

Elongation of inch sections: .14 inch (.29 inch fractured section), .21 inch.

No. 376.



[Marks on bar, B. B.; diameter, .564 inch; sectional area, .25 square inch.]

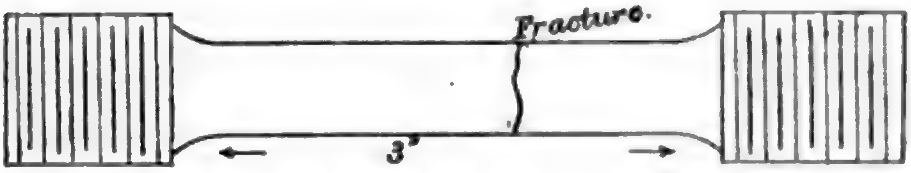
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000133	.000133	0.	....	
2, 500	10, 000	.000267	.000134	0.	....	
3, 750	15, 000	.000400	.000133	0.	....	
5, 000	20, 000	.000633	.000233	.000133	.000133	
6, 250	25, 000	.000900	.000267	.000167	.000034	
7, 500	30, 000	.001133	.000233	.000233	.000066	
7, 750	31, 000	.001200	.000067	....	....	
8, 000	32, 000	.001267	.000067	....	....	
8, 250	33, 000	.001300	.000033	....	....	Elastic limit.
8, 500	34, 000	.001533	.000233	....	....	
8, 750	35, 000	.002067	.000534	.001067	.000834	
9, 000	36, 000	.003300	.001233	....	....	
9, 250	37, 000	.004100	.000800	....	....	
9, 500	38, 000	.006267	.002167	....	....	
9, 750	39, 000	.006767	.000500	....	....	
10, 000	40, 000	.007967	.001200	.006433	.005366	
10, 250	41, 000	.008300	.000333	....	....	
10, 500	42, 000	.009267	.000967	....	....	
10, 750	43, 000	.009867	.000600	....	....	
11, 000	44, 000	.010533	.000666	....	....	
11, 250	45, 000	.011833	.001300	.010233	.003800	
11, 500	46, 000	.012767	.000934	....	....	
11, 750	47, 000	.013600	.000833	....	....	
12, 000	48, 000	.015100	.001500	....	....	
12, 250	49, 000	.016000	.000900	....	....	
12, 500	50, 000	.017333	.001333	.015433	.005200	
13, 000	52, 000	.019400	.002067	....	....	
13, 500	54, 000	.021933	.002533	....	....	
14, 000	56, 000	.024600	.002667	....	....	
14, 500	58, 000	.027600	.003000	....	....	
15, 000	60, 000	.031667	.004067	....	....	
15, 500	62, 000	.035767	.004100	....	....	
16, 000	64, 000	.038733	.002966	....	....	
16, 500	66, 000	.044667	.005934	....	....	
17, 000	68, 000	.050333	.005666	....	....	
17, 500	70, 000	.058000	.007667	....	....	Micrometer removed.
18, 000	72, 000	.0633	.0053	....	....	
18, 500	74, 000	.0783	.0150	....	....	
19, 000	76, 000	.0933	.0150	....	....	
19, 500	78, 000	.1167	.0234	....	....	
19, 720	78, 880	.1500	.0333	....	....	Ultimate strength.
18, 800	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	78, 880
Elastic limit per square inch of original section	do	32, 000
Elongation per inch after rupture	inch	0. 19
Elongation per inch under strain at elastic limit	do	.001300
Reduction in diameter at point of rupture	do	.114
Reduction in area after rupture, per centum of original section		36.4
Position of rupture		.60 inch from neck.
Character of broken surface		fine granular. Dull spot at circumference of fractured surface. Fine cracks developed on cylindrical surface of bar in the vicinity of the fracture.

Elongation of inch sections: .13 inch, .15 inch (.29 inch fractured section).

No. 377.



[Marks on bar, J J; diameter, .564 inch; sectional area, .25 square inch.]

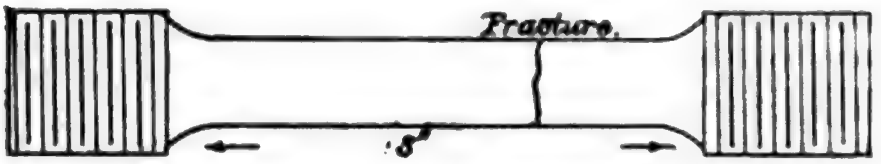
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000133	.000133	0.	....	
2, 500	10, 000	.000267	.000134	0.	....	
3, 750	15, 000	.000400	.000133	0.	....	
5, 000	20, 000	.000600	.000200	0.	....	
6, 250	25, 000	.000800	.000200	.000100	.000100	
7, 500	30, 000	.001300	.000500	.000367	.000267	Elastic limit.
7, 750	31, 000	.001967	.000667	....	....	
8, 000	32, 000	.002633	.000666	....	....	
8, 250	33, 000	.003100	.000467	....	....	
8, 500	34, 000	.003967	.000867	....	....	
8, 750	35, 000	.004500	.000533	.003267	.002900	
9, 000	36, 000	.005333	.000833	....	....	
9, 250	37, 000	.006000	.000667	....	....	
9, 500	38, 000	.006933	.000933	....	....	
9, 750	39, 000	.007467	.000534	....	....	
10, 000	40, 000	.008300	.000833	.006833	.003566	
10, 250	41, 000	.008933	.000633	....	....	
10, 500	42, 000	.009767	.000834	....	....	
10, 750	43, 000	.010600	.000833	....	....	
11, 000	44, 000	.011933	.001333	....	....	
11, 250	45, 000	.012600	.000667	.010833	.004000	
11, 500	46, 000	.013700	.001100	....	....	
11, 750	47, 000	.014433	.000733	....	....	
12, 000	48, 000	.015733	.001300	....	....	
12, 250	49, 000	.016567	.000834	....	....	
12, 500	50, 000	.018100	.001533	.016067	.005234	
13, 000	52, 000	.020067	.001967	....	....	
13, 500	54, 000	.022900	.002833	....	....	
14, 000	56, 000	.025400	.002500	....	....	
14, 500	58, 000	.028100	.002700	....	....	
15, 000	60, 000	.031300	.003200	....	....	
15, 500	62, 000	.035400	.004100	....	....	
16, 000	64, 000	.039733	.004333	....	....	
16, 500	66, 000	.045633	.005900	....	....	
17, 000	68, 000	.050600	.004967	....	....	
17, 500	70, 000	.059667	.009067	....	....	Micrometer removed.
18, 000	72, 000	.0700	.010333	....	....	
18, 500	74, 000	.0800	.0100	....	....	
19, 000	76, 000	.0967	.0167	....	....	
19, 500	78, 000	.1267	.0300	....	....	
19, 830	79, 320	.1800	.0533	....	....	Ultimate strength.
17, 900	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity	
Hardness	
Tensile strength per square inch of original section ... pounds..	79, 820
Elastic limit per square inch of original section ... do....	30, 000
Elongation per inch after rupture ... inch..	0. 2333
Elongation per inch under strain at elastic limit ... do ...	.001300
Reduction in diameter at point of rupture ... do....	.104
Reduction in area after rupture, per centum of original section	33. 5
Position of rupture	1.10 inches from neck.
Character of broken surface	granular. Dull spot at circumference, and small dull pockets in the granular metal. Cracks developed on the cylindrical surface of bar in vicinity of fracture.

Elongation of inch sections: .17 inch, .27 inch (.26 inch fractured section).

No. 378.



[Marks on bar, H H; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	....	Initial load.
1, 250	5, 000	.000133	.000133	0.	....	
2, 500	10, 000	.000267	.000134	0.	....	
3, 750	15, 000	.000400	.000133	0.	....	
5, 000	20, 000	.000600	.000200	.000033	.000032	
5, 250	21, 000	.000600	0.	....	....	
5, 500	22, 000	.000633	.000033	....	....	
5, 750	23, 000	.000667	.000034	....	....	
6, 000	24, 000	.000700	.000033	....	....	
6, 250	25, 000	.000733	.000033	.000067	.000034	
6, 500	26, 000	.000767	.000034	....	....	
6, 750	27, 000	.000800	.000033	....	....	
7, 000	28, 000	.000833	.000033	....	....	
7, 250	29, 000	.000867	.000034	....	....	
7, 500	30, 000	.000900	.000033	.000100	.000033	
7, 750	31, 000	.000933	.000033	....	....	
8, 000	32, 000	.001000	.000067	....	....	
8, 250	33, 000	.001000	0.	....	....	
8, 500	34, 000	.001033	.000033	....	....	
8, 750	35, 000	.001067	.000034	.000100	0.	
9, 000	36, 000	.001100	.000033	....	....	
9, 250	37, 000	.001133	.000033	....	....	
9, 500	38, 000	.001167	.000034	....	....	
9, 750	39, 000	.001200	.000033	....	....	
10, 000	40, 000	.001233	.000033	.000100	0.	
10, 250	41, 000	.001267	.000034	....	....	
10, 500	42, 000	.001300	.000033	....	....	
10, 750	43, 000	.001333	.000033	....	....	
11, 000	44, 000	.001367	.000034	....	....	
11, 250	45, 000	.001400	.000033	.000100	0.	
11, 500	46, 000	.001400	0.	....	....	
11, 750	47, 000	.001433	.000033	....	....	
12, 000	48, 000	.001467	.000034	....	....	
12, 250	49, 000	.001500	.000033	....	....	
12, 500	50, 000	.001533	.000033	.000100	0.	Elastic limit.
12, 750	51, 000	.001733	.000200	....	....	
Rapid stretching. Load fell to 47,000 pounds per square inch.						
11, 750	47, 000	.006667	.004934	....	....	
12, 750	51, 000	.011833	.005166	....	....	
13, 000	52, 000	.012033	.000200	....	....	
13, 250	53, 000	.012333	.000300	....	....	
13, 500	54, 000	.013367	.001034	....	....	
13, 750	55, 000	.014100	.000733	.012033	.011933	
14, 000	56, 000	.015233	.001133	....	....	
14, 250	57, 000	.015900	.000667	....	....	

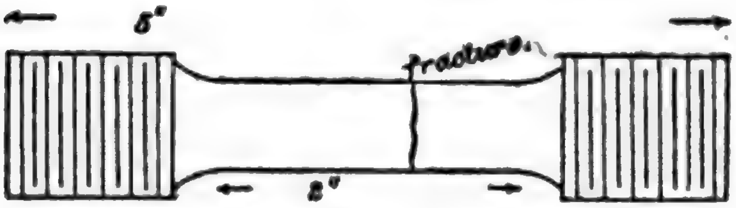
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch*	*Inch.*	*Inch.*	*Inch.*	
14, 500	58, 000	. 016867	. 000967	....	....	
14, 750	59, 000	. 018100	. 001233	....	....	
15, 000	60, 000	. 019233	. 001133	. 016800	. 004767	
15, 500	62, 000	. 021600	. 002367	....	....	
16, 000	64, 000	. 024067	. 002467	....	....	
16, 500	66, 000	. 027067	. 003000	....	....	
17, 000	68, 000	. 030367	. 003300	....	....	
17, 500	70, 000	. 033333	. 002966	....	....	
18, 000	72, 000	. 037400	. 004067	....	....	
18, 500	74, 000	. 042000	. 004600	....	....	
19, 000	76, 000	. 046667	. 004667	....	....	
19, 500	78, 000	. 052833	. 006166	....	....	
20, 000	80, 000	. 060500	. 007667	....	....	
20, 500	82, 000	. 068700	. 008200	....	....	Micrometer removed.
21, 000	84, 000	. 0833	. 0146	....	....	
21, 500	86, 000	. 1033	. 0200	....	....	
22, 000	88, 000	. 1433	. 0400	....	....	
22, 100	88, 400	. 1767	. 0334	....	....	Ultimate strength.
19, 100	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	88, 400
Elastic limit per square inch of original section	do	60, 000
Elongation per inch after rupture	inch	0. 2233
Elongation per inch under strain at elastic limit	do	. 001533
Reduction in diameter at point of rupture	do	. 154
Reduction in area after rupture, per centum of original section		47. 2
Position of rupture		.90 inch from neck.
Character of broken surface		fine, silky; trace of granulation.

Elongation of inch sections: .11 inch, .17 inch (.39 inch fractured section).

No. 379.



[Marks on bar, L A; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	. 000100	. 000100	0.	....	
2, 500	10, 000	. 000200	. 000100	0.	....	
3, 750	15, 000	. 000400	. 000200	0.	....	
5, 000	20, 000	. 000550	. 000150	0.	....	
6, 250	25, 000	. 000650	. 000100	. 000050	. 000050	
6, 500	26, 000	. 000750	. 000100	....	....	
6 750	27, 000	. 000800	. 000050	....	....	
7, 000	28, 000	. 000850	. 000050	....	....	
7, 250	29, 000	. 000900	. 000050	....	....	

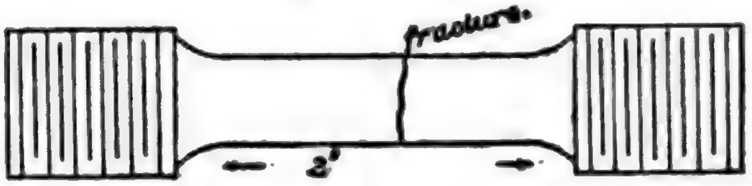
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Permanent.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
7, 500	30, 000	.000900	0.	.000050	0.	
7, 750	31, 000	.000900	0.			
8, 000	32, 000	.000950	.000050			
8, 250	33, 000	.001000	.000050			
8, 500	34, 000	.001000	0.			
8, 750	35, 000	.001000	0.	.000050	0.	
9, 000	36, 000	.001100	.000100			
9, 250	37, 000	.001150	.000050			
9, 500	38, 000	.001150	0.			
9, 750	39, 000	.001200	.000050			
10, 000	40, 000	.001200	0.	.000050	0.	
10, 250	41, 000	.001250	.000050			
10, 500	42, 000	.001300	.000050			
10, 750	43, 000	.001300	0.			
11, 000	44, 000	.001350	.000050			
11, 250	45, 000	.001350	0.	.000050	0.	
11, 500	46, 000	.001400	.000050			
11, 750	47, 000	.001450	.000050			
12, 000	48, 000	.001500	.000050			
12, 250	49, 000	.001500	0.			
12, 500	50, 000	.001550	.000050	.000050	0.	
12, 750	51, 000	.001550	0.			
13, 000	52, 000	.001600	.000050			
13, 250	53, 000	.001600	0.			
13, 500	54, 000	.001650	.000050			
13, 750	55, 000	.001750	.000100	.000150	.000100	Elastic limit.
14, 000	56, 000	.008350	.006600			
14, 250	57, 000	.008550	.000200			
14, 500	58, 000	.009400	.000850			
14, 750	59, 000	.009700	.000300			
15, 000	60, 000	.010650	.000950	.008400	.008250	
15, 500	62, 000	.011850	.001200			
16, 000	64, 000	.014250	.002400			
16, 500	66, 000	.015850	.001600			
17, 000	68, 000	.017750	.001900			
17, 500	70, 000	.020050	.002300			
18, 000	72, 000	.022050	.002000			
18, 500	74, 000	.025150	.003100			
19, 000	76, 000	.027050	.001900			
19, 500	78, 000	.030200	.003150			
20, 000	80, 000	.033650	.003450			Micrometer removed.
20, 500	82, 000	.0350	.001350			
21, 000	84, 000	.0375	.0025			
21, 500	86, 000	.0400	.0025			
22, 000	88, 000	.0475	.0075			
22, 500	90, 000	.0550	.0075			
23, 000	92, 000	.0650	.0100			
23, 500	94, 000	.0800	.0150			
24, 000	96, 000	.1100	.0300			
24, 070	96, 280	.1350	.0250			Ultimate strength.
20, 000						Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds.	96, 280
Elastic limit per square inch of original section	do	55, 000
Elongation per inch after rupture	inch	0. 255
Elongation per inch under strain at elastic limit	do	.001750
Reduction in diameter at point of rupture	do	.174
Reduction in area after rupture, per centum of original section		52. 2
Position of rupture		.75 inch from neck.
Character of broken surface		fine silky, trace of granulation. Cup-shaped ends.

Elongation of inch sections: .14 inch (.37 inch fractured section).

No. 380.



[Marks on bar, L. B; diameter, .564 inch; sectional area, .25 square inch.]

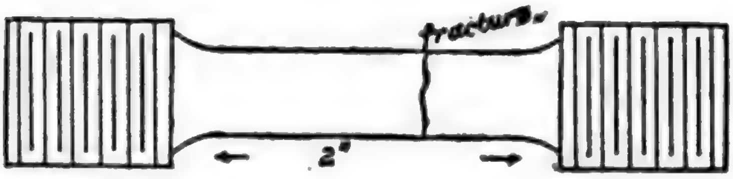
Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000250	.000150	0.	....	
3, 750	15, 000	.000350	.000100	0.	....	
5, 000	20, 000	.000550	.000200	0.	....	
5, 250	21, 000	.000550	0.	....	....	
5, 500	22, 000	.000600	.000050	....	....	
5, 750	23, 000	.000650	.000050	....	....	
6, 000	24, 000	.000650	0.	....	....	
6, 250	25, 000	.000700	.000050	.000050	.000050	
6, 500	26, 000	.000750	.000050	....	....	
6, 750	27, 000	.000800	.000050	....	....	
7, 000	28, 000	.000900	.000100	....	....	
7, 250	29, 000	.000950	.000050	....	....	
7, 500	30, 000	.001000	.000050	.000100	.000050	
7, 750	31, 000	.001050	.000050	....	....	Elastic limit.
8, 000	32, 000	.001150	.000100	....	....	
8, 250	33, 000	.001250	.000100	....	....	
8, 500	34, 000	.001400	.000150	....	....	
8, 750	35, 000	.001800	.000400	.000650	.000550	
9, 000	36, 000	.002150	.000350	....	....	
9, 250	37, 000	.002650	.000500	....	....	
9, 500	38, 000	.004100	.001450	....	....	
9, 750	39, 000	.004900	.000800	....	....	
10, 000	40, 000	.006000	.001100	.004450	.003800	
10, 250	41, 000	.006500	.000500	....	....	
10, 500	42, 000	.007500	.001000	....	....	
10, 750	43, 000	.008200	.000700	....	....	
11, 000	44, 000	.009000	.000800	....	....	
11, 250	45, 000	.009750	.000750	.007950	.003500	
11, 500	46, 000	.010500	.000750	....	....	
11, 750	47, 000	.011000	.000500	....	....	
12, 000	48, 000	.012250	.001250	....	....	
12, 250	49, 000	.012800	.000550	....	....	
12, 500	50, 000	.014400	.001600	.012250	.004300	
13, 000	52, 000	.016100	.001700	....	....	
13, 500	54, 000	.018250	.002150	....	....	
14, 000	56, 000	.020200	.001950	....	....	
14, 500	58, 000	.023250	.003050	....	....	
15, 000	60, 000	.025400	.002150	....	....	
15, 500	62, 000	.028700	.003300	....	....	
16, 000	64, 000	.032250	.003550	....	....	
15, 500	66, 000	.035350	.003100	....	....	
17, 000	68, 000	.039550	.004200	....	....	
17, 500	70, 000	.045650	.006100	....	....	
18, 000	72, 000	.050000	.004350	....	....	
18, 500	74, 000	.059350	.009350	....	....	
19, 000	76, 000	.067600	.008250	....	....	
19, 500	78, 000	.080000	.012400	....	....	Micrometer removed.
20, 000	80, 000	.1000	.0200	....	....	
20, 500	82, 000	.1325	.0325	....	....	
20, 710	82, 840	.1750	.0425	....	....	Ultimate strength.
18, 000	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds	82, 840
Elastic limit per square inch of original section	do	31, 000
Elongation per inch after rupture	inch	0. 315
Elongation per inch under strain at elastic limit	do	.001050
Reduction in diameter at point of rupture	do	.164
Reduction in area after rupture, per centum of original section		49. 7
Position of rupture		.85 inch from neck.
Character of broken surface		granular and dull spongy. Cylindrical surface of bar mottled in vicinity of fracture.

Elongation of inch sections: .19 inch (.44 inch fractured section).

No. 381.



[Marks on bar, L. C.; diameter, .564 inch; sectional area, .25 square inch.]

Applied loads.		Elongation per inch.	Successive elongation per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
250	1, 000	0.	0.	0.	0.	Initial load.
1, 250	5, 000	.000100	.000100	0.	....	
2, 500	10, 000	.000250	.000150	0.	....	
3, 750	15, 000	.000450	.000200	0.	....	
5, 000	20, 000	.000550	.000100	.000050	.000050	
5, 250	21, 000	.000600	.000050	....	....	
5, 500	22, 000	.000650	.000050	....	....	
5, 750	23, 000	.000700	.000050	....	....	
6, 000	24, 000	.000800	.000100	....	....	
6, 250	25, 000	.000850	.000050	.000050	0.	
6, 500	26, 000	.000850	0.	....	....	
6, 750	27, 000	.000850	0.	....	....	
7, 000	28, 000	.000900	.000050	....	....	
7, 250	29, 000	.000950	.000050	....	....	
7, 500	30, 000	.001000	.000050	.000100	.000050	
7, 750	31, 000	.001030	.000050	....	....	
8, 000	32, 000	.001050	0.	....	....	
8, 250	33, 000	.001100	.000050	....	....	
8, 500	34, 000	.001150	.000050	....	....	Elastic limit.
8, 750	35, 000	.001250	.000100	.000200	.000100	
9, 000	36, 000	.001550	.000300	....	....	
9, 250	37, 000	.001800	.000250	....	....	
9, 500	38, 000	.002450	.000650	....	....	
9, 750	39, 000	.002950	.000500	....	....	
10, 000	40, 000	.003500	.000550	.002050	.001850	
10, 250	41, 000	.003850	000350	....	....	
10, 500	42, 000	.004650	.000800	....	....	
10, 750	43, 000	.005550	.000900	....	....	
11, 000	44, 000	.006350	.000800	....	....	
11, 250	45, 000	.007100	.000750	.005550	.003500	
11, 500	46, 000	.007950	.000850	....	....	
11, 750	47, 000	.008550	.000600	....	....	
12, 000	48, 000	.009650	.001100	....	....	
12, 250	49, 000	.010350	.000700	....	....	
12, 500	50, 000	.011600	.001250	.009600	.004050	
13, 000	52, 000	.013000	.001400	....	....	
13, 500	54, 000	.015500	.002500	....	....	
14, 000	56, 000	.017100	.001600	....	....	
14, 500	58, 000	.019200	.002100	....	....	
15, 000	60, 000	.022100	.002900	....	....	
15, 500	62, 000	.024650	.002550	....	....	
16, 000	64, 000	.028100	.003450	....	....	
16, 500	66, 000	.031200	.003100	....	....	
17, 000	68, 000	.034500	.003300	....	....	
17, 500	70, 000	.038650	.004150	....	....	
18, 000	72, 000	.043600	.004950	....	....	
18, 500	74, 000	.050000	.006400	....	....	
19, 000	76, 000	.058000	.008000	....	....	
19, 500	78, 000	.065500	.007500	....	....	
20, 000	80, 000	.077500	.012000	....	....	Micrometer removed.
20, 500	82, 000	.0975	.0200	....	....	
21, 000	84, 000	.1325	.0350	....	....	
21, 150	84, 600	.1750	.0425	....	....	Ultimate strength.
18, 400	....	....	....	....	....	Load at time of fracture.

GENERAL SUMMARY.

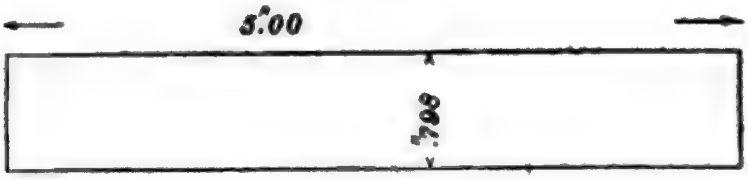
Specific gravity		
Hardness		
Tensile strength per square inch of original section	pounds..	84, 600
Elastic limit per square inch of original section	do...	34, 000
Elongation per inch after rupture	inch..	0. 28
Elongation per inch under strain at elastic limit	do...	.001150
Reduction in diameter at point of rupture	do...	.164
Reduction in area after rupture, per centum of original section		49. 7
Position of rupture		.65 inch from neck.
Character of broken surface		dull spongy. Cylindrical surface of bar mottled in vicinity of fracture.

Elongation of inch sections: .15 inch (.41 inch fractured section).

TESTS BY COMPRESSION: FOUR SPECIMENS WHITWORTH STEEL FROM JACKET OF 8-INCH BREECH-LOADING RIFLE; FIVE SPECIMENS WHITWORTH STEEL FROM TUBE OF 8-INCH BREECH-LOADING RIFLE.

August 5, 1884.

No. 392.



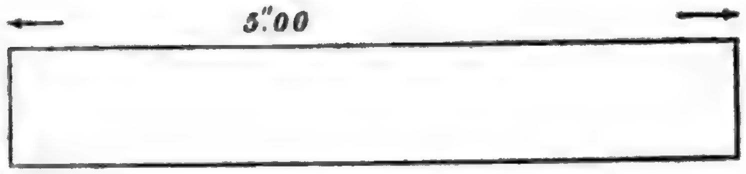
[Marks on bar, C. C.; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	0.	0.	0.	Initial load.
2,500	2,500	.000075	.000075	0.	....	
5,000	10,000	.000250	.000175	0.	....	
7,500	15,000	.000425	.000175	0.	....	
10,000	20,000	.000525	.000100	0.	....	
12,500	25,000	.000700	.000175	0.	....	
13,000	26,000	.000750	.000050	....	....	
13,500	27,000	.000775	.000025	....	....	
14,000	28,000	.000800	.000025	....	....	
14,500	29,000	.000825	.000025	....	....	
15,000	30,000	.000850	.000025	0.	....	
15,500	31,000	.000900	.000050	....	....	
16,000	32,000	.000975	.000075	....	....	
16,500	33,000	.001000	.000025	....	....	
17,000	34,000	.001025	.000025	....	....	
17,500	35,000	.001050	.000025	0.	....	
18,000	36,000	.001125	.000075	....	....	Elastic limit.
18,500	37,000	.001550	.000425	....	....	Rapid deflection.
19,000	38,000	.002300	.000750	....	....	
19,500	39,000	.003625	.001325	....	....	
20,000	40,000	.004225	.000600	....	....	Rested under load one hour.
		.004450	.000225	.003000	.003000	Compression and set after rest.
20,500	41,000	.004675	.000225	....	....	
21,000	42,000	.005225	.000550	....	....	
21,500	43,000	.006050	.000825	....	....	
22,000	44,000	.006675	.000625	....	....	
22,500	45,000	.007400	.000725	.005750	.002750	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section	pounds..	36,000
Compression per inch under strain at elastic limit	inch..	.001125

No. 393.



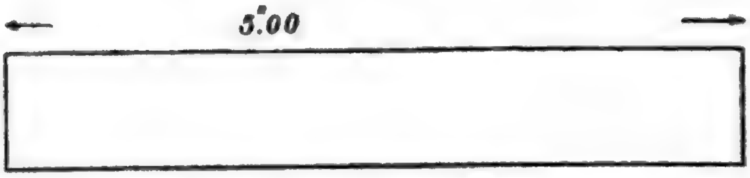
[Marks on bar, D D; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	0.	0.	0.	Initial load.
2, 500	5, 000	.000150	.000150	0.	....	
5, 000	10, 000	.000300	.000150	0.	....	
7, 500	15, 000	.000450	.000150	0.	....	
10, 000	20, 000	.000600	.000150	0.	....	
12, 500	25, 000	.000750	.000150	0.	....	
13, 000	26, 000	.000875	.000125	....	....	
13, 500	27, 000	.000900	.000025	....	....	
14, 000	28, 000	.000925	.000025	....	....	
14, 500	29, 000	.000975	.000050	....	....	
15, 000	30, 000	.001000	.000025	.000050	.000050	
15, 500	31, 000	.001050	.000050	....	....	
16, 000	32, 000	.001075	.000025	....	....	Elastic limit.
16, 500	33, 000	.001150	.000075	....	....	
17, 000	34, 000	.001225	.000075	....	....	
17, 500	35, 000	.001300	.000075	.000250	.000200	
18, 000	36, 000	.001525	.000225	....	....	Rapid deflection.
18, 500	37, 000	.002050	.000525	....	....	
19, 000	38, 000	.002925	.000875	....	....	
19, 500	39, 000	.004050	.001125	....	....	
20, 000	40, 000	.004925	.000875	.003425	.003175	
20, 500	41, 000	.005725	.000800	....	....	
21, 000	42, 000	.006575	.000850	....	....	
21, 500	43, 000	.007725	.001150	....	....	
22, 000	44, 000	.008450	.000725	....	....	
22, 000	45, 000	.009500	.001050	.007725	.004300	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section	pounds..	32, 000
Compression per inch under strain at elastic limit	inch..	.001075
Compression per inch under 35,000 pounds per square inch	do....	.001300

No. 394.



[Marks on bar, E E; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	0.	0.	0.	Initial load.
2,500	5,000	.000175	.000175	0.		
5,000	10,000	.000325	.000150	0.		
7,500	15,000	.000450	.000125	0.		
10,000	20,000	.000600	.000150	.000075	.000075	
12,500	25,000	.000800	.000200	.000100	.000025	
13,000	26,000	.000875	.000075			
13,500	27,000	.000925	.000050			
14,000	28,000	.000950	.000025			
14,500	29,000	.000975	.000025			
15,000	30,000	.001025	.000050	.000125	.000025	
15,500	31,000	.001075	.000050			
16,000	32,000	.001150	.000075			
16,500	33,000	.001200	.000050			Elastic limit.
17,000	34,000	.001300	.000100			
17,500	35,000	.001875	.000575	.000800	.000675	Rapid deflection.
18,000	36,000	.004475	.002600			
18,500	37,000	.005800	.001325			
19,000	38,000	.006500	.000700			
19,500	39,000	.007275	.000775			
20,000	40,000	.008175	.000900	.006750	.005950	
20,500	41,000	.008825	.000650			
21,000	42,000	.009800	.000975			
21,500	43,000	.010575	.000775			
22,000	44,000	.011500	.000925			
22,500	45,000	.012550	.001050	.011000	.004250	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section	pounds	33,000
Compression per inch under strain at elastic limit	inch	.001200
Compression per inch under 34,000 pounds per square inch	do	.001300

No. 395.

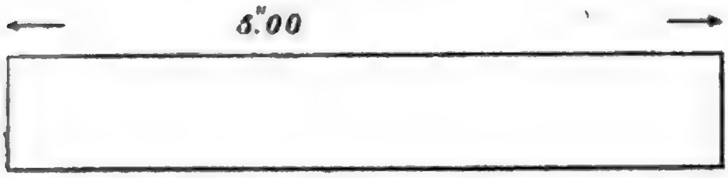
[Marks on bar, I I; diameter, .798 inch; sectional area, .50 square inch.]

Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	0.	0.	0.	Initial load.
2, 500	5, 000	.000225	.000225	.000025	.000025	
5, 000	10, 000	.000450	.000225	.000025	0.	
7, 500	15, 000	.000550	.000100	.000025	0.	
10, 000	20, 000	.000725	.000175	.000050	.000025	
12, 500	25, 000	.000925	.000200	.000150	.000100	
13, 000	26, 000	.001000	.000075	....	....	
13, 500	27, 000	.001050	.000050	....	....	Elastic limit.
14, 000	28, 000	001125	.000075	....	....	
14, 500	29, 000	.001225	.000100	....	....	
15, 000	30, 000	.001350	.000125	.000375	.000225	
15, 500	31, 000	.001550	.000200	....	....	
16, 000	32, 000	.002125	.000575	....	....	
16, 500	33, 000	.002425	.000300	....	....	
17, 000	34, 000	.002700	.000275	....	....	
17, 500	35, 000	.003200	.000500	.001900	.001525	
18, 000	36, 000	.003575	.000375	....	....	
18, 500	37, 000	.004125	.000550	....	....	Perceptible deflection.
19, 000	38, 000	.005250	.001125	....	....	
19, 500	39, 000	.006025	.000775	....	....	
20, 000	40, 000	.006675	.000650	.005100	.003200	
20, 500	41, 000	.007375	.000700	....	....	
21, 000	42, 000	.008125	.000750	....	....	
21, 500	43, 000	.008975	.000850	....	....	
22, 000	44, 000	.009700	.000725	....	....	
22, 500	45, 000	.010450	.000750	.008800	.003700	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section ....pounds..	27, 000
Compression per inch under strain at elastic limit..................................inch..	.001050
Compression per inch under 36,000 pounds per square inch..............................do....	.003575

No. 396.



[Marks on bar, K K; diameter, .798 inch; sectional area, .50 square inch.]

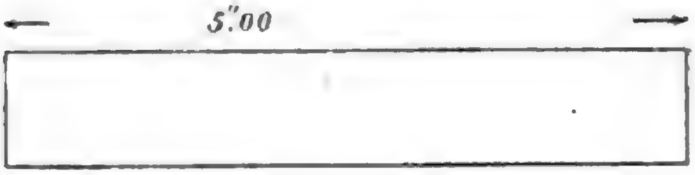
Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	0.	0.	0.	Initial load.
2, 500	5, 000	.000100	.000100	0.	....	
5, 000	10, 000	.000275	.000175	0.	....	
7, 500	15, 000	.000475	.000200	0.	....	
10, 000	20, 000	.000575	.000100	0.	....	
12, 500	25, 000	.000800	.000225	0.	....	
13, 000	26, 000	.000825	.000025	....	....	
13, 500	27, 000	.000850	.000025	....	....	
14, 000	28, 000	.000875	.000025	....	....	
14, 500	29, 000	.000925	.000050	....	....	
15, 000	30, 000	.000950	.000025	0.	....	
15, 500	31, 000	.001000	.000050	....	....	
16, 000	32, 000	.001025	.000025	....	....	
16, 500	33, 000	.001050	.000025	....	....	
17, 000	34, 000	.001100	.000050	....	....	
17, 500	35, 000	.001200	.000100	0.	....	
18, 000	36, 000	.001250	.000050	....	....	
18, 500	37, 000	.001275	.000025	....	....	
19, 000	38, 000	.001300	.000025	....	....	
19, 500	39, 000	.001325	.000025	....	....	
20, 000	40, 000	.001425	.000100	0.	....	Elastic limit.
20, 500	41, 000	.001550	.000125	....	....	
21, 000	42, 000	.001750	.000200	....	....	
21, 500	43, 000	.002675	.000925	....	....	Perceptible deflection.
22, 000	44, 000	.003825	.001150	....	....	
22, 500	45, 000	.005000	.001175	.003375	.003375	
23, 000	46, 000	.005275	.000275	....	....	
23, 500	47, 000	.005950	.000675	....	....	
24, 000	48, 000	.006700	.000750	....	....	
24, 500	49, 000	.007500	.000800	....	....	
25, 000	50, 000	.008750	.001250	.006775	.003400	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section ....pounds.. 40,000
Compression per inch under strain at elastic limit ....inch.. .001425
Compression per inch under 42,000 pounds per square inch ....do.... .001750

The direction of deflection was reversed as the loads were increased from 43,000 pounds per square inch to 50,000 pounds per square inch.

No. 397.



[Marks on bar, M M; diameter, .798 inch; sectional area, .50 square inch.]

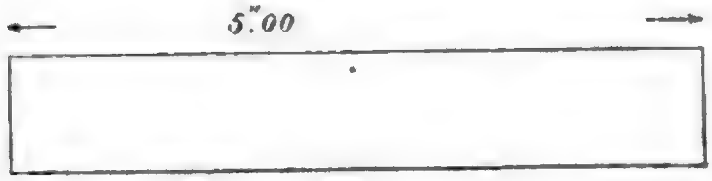
Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1,000	0.	0.	0.	0.	Initial load.
2,500	5,000	.000125	.000125	0.	....	
5,000	10,000	.000300	.000175	0.	....	
7,500	15,000	.000500	.000200	.000050	.000050	
10,000	20,000	.000675	.000175	.000100	.000050	
10,500	21,000	.000675	0.	....	....	
11,000	22,000	.000750	.000075	....	....	
11,500	23,000	.000725	.000025	....	....	
12,000	24,000	.000750	.000025	....	....	
12,500	25,000	.000800	.000050	.000125	.000025	
13,000	26,000	.000875	.000075	....	....	
13,500	27,000	.000900	.000025	....	....	
14,000	28,000	.000950	.000050	....	....	
14,500	29,000	.000950	0.	....	....	
15,000	30,000	.000975	.000025	.000125	0.	Elastic limit.
15,500	31,000	.001075	.000100	....	....	
16,000	32,000	.001225	.000150	....	....	
16,500	33,000	.001450	.000225	....	....	
17,000	34,000	.001750	.000300	....	....	Perceptible deflection.
17,500	35,000	.002000	.000250	.000950	.000825	
18,000	36,000	.002500	.000500	....	....	
18,500	37,000	.002850	.000350	....	....	
19,000	38,000	.003100	.000250	....	....	
19,500	39,000	.003925	.000825	....	....	
20,000	40,000	.004400	.000475	.003000	.002050	
20,500	41,000	.004775	.000375	....	....	
21,000	42,000	.005350	.000575	....	....	
21,500	43,000	.005925	.000575	....	....	
22,000	44,000	.006675	.000750	....	....	
22,500	45,000	.007375	.000700	.005750	.002750	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section ....pounds.. 30,000
Compression per inch under strain at elastic limit ....inch.. .000075
Compression per inch under 33,000 pounds per square inch ....do... .001450

There was no appreciable permanent enlargement of the diameter of the bar at one end; along the middle of its length and at the other end the enlargement in diameter was .003 inch.

No 398.



[Marks on bar, N N; diameter, .798 inch; sectional area, .50 square inch.]

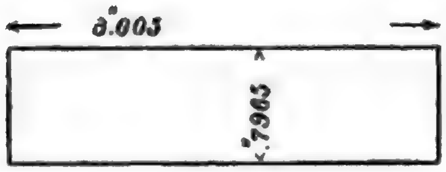
Applied loads.		Compression per inch.	Successive compression per inch.	Permanent set.	Successive permanent set.	Remarks.
Total.	Per square inch.					
Pounds.	*Pounds.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	
500	1, 000	0.	0.	0.	0.	Initial load.
2, 500	5, 000	.000150	.000150	0.	....	
5, 000	10, 000	.000275	.000125	0.	....	
7, 500	15, 000	.000450	.000175	0.	....	
10, 000	20, 000	.000625	.000175	.000025	.000025	
12, 500	25, 000	.000775	.000150	.000050	.000025	
13, 000	26, 000	.000775	0.	....	....	
13, 500	27, 000	.000875	.000100	....	....	
14, 000	28, 000	.000925	.000050	....	....	
14, 500	29, 000	.000975	.000050	....	....	Elastic limit.
15, 000	30, 000	.001125	.000150	.000225	.000175	
15, 500	31, 000	.001250	.000125	....	....	
16, 000	32, 000	.001525	.000275	....	....	
16, 500	33, 000	.002100	.000575	....	....	
17, 000	34, 000	.002625	.000525	....	....	Perceptible deflection.
17, 500	35, 000	.003300	.000675	.002225	.002000	
18, 000	36, 000	.003950	.000650	....	....	
18, 500	37, 000	.004650	.000700	....	....	
19, 000	38, 000	.005175	.000525	....	....	
19, 500	39, 000	.005975	.000800	....	....	
20, 000	40, 000	.006700	.000725	.005175	.002950	
20, 500	41, 000	.007250	.000550	....	....	
21, 000	42, 000	.007950	.000700	....	....	
21, 500	43, 000	.008725	.000775	....	....	
22, 000	44, 000	.009475	.000750	....	....	
22, 500	45, 000	.010175	.000700	.008500	.003325	Test discontinued.

GENERAL SUMMARY.

Elastic limit per square inch of original section	pounds	29, 000
Compression per inch under strain at elastic limit	inch	.000975
Compression per inch under 33,000 pounds per square inch	do	.002100

Crushing specimen.

No. 399.

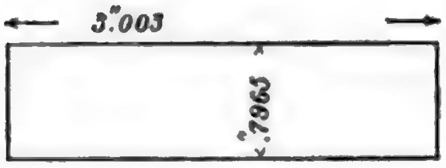


[Marks on bar, F F; length, 3.005 inches; diameter, .7965 inch; sectional area, .498 square inch.]

Specimen loaded with 74,700 pounds=150,000 per square inch.
Distortion took place by deflecting laterally and the sides swelling.
Length of specimen after the test, 1.68 inches.

Crushing specimen.

No. 400.



[Marks on bar, G G; length, 3.003 inches; diameter, .7965 inch; sectional area, .498 square inch.]

Specimen loaded with 74,700 pounds=50,000 pounds per square inch.
Distortion took place by deflecting laterally and the sides swelling.
Length of specimen after the test, 1.65 inches.

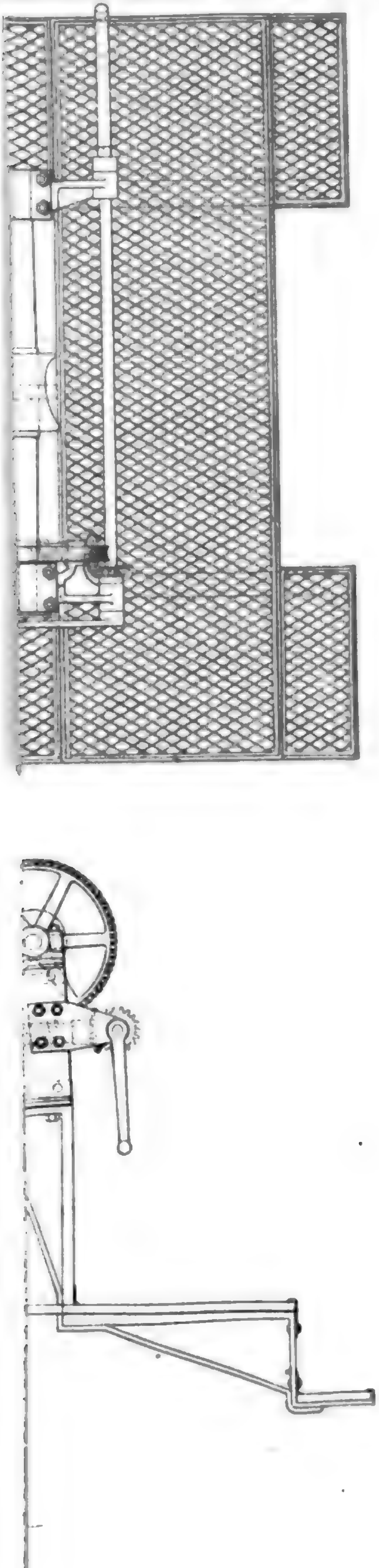
F. H. PARKER,
Major Ordnance Department, U. S. Army, Commanding.

APPENDIX 37.

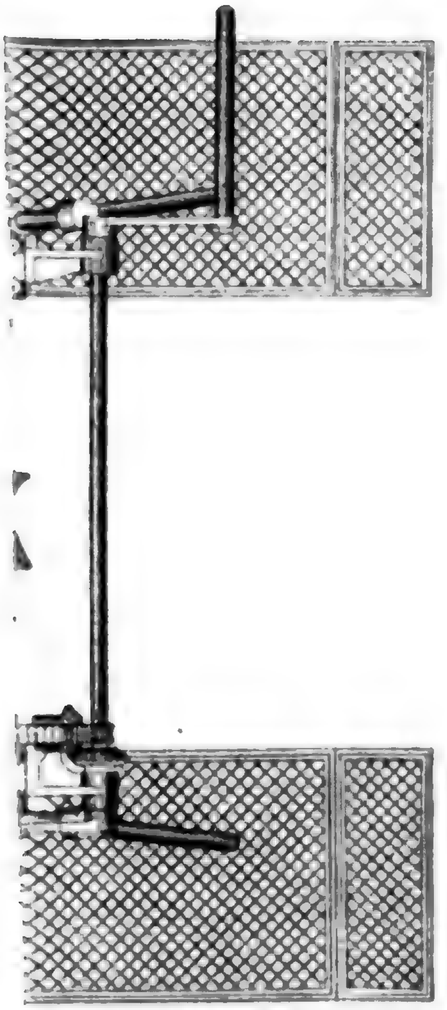
THE BARBETTE CARRIAGE FOR 15-INCH SMOOTH-BORE GUN AND 11-INCH RIFLE.

(2 PLATES.)

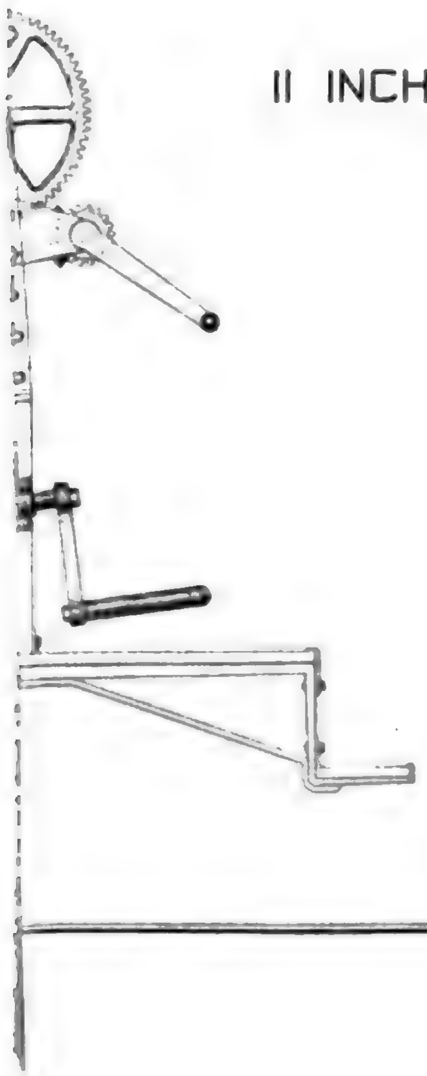
PLATE I.



Appendix 37—1884.



BARBETTE CARRIAGE MODEL 1883
FOR
11 INCH RIFLE GUN.



Appendix 37—1884.

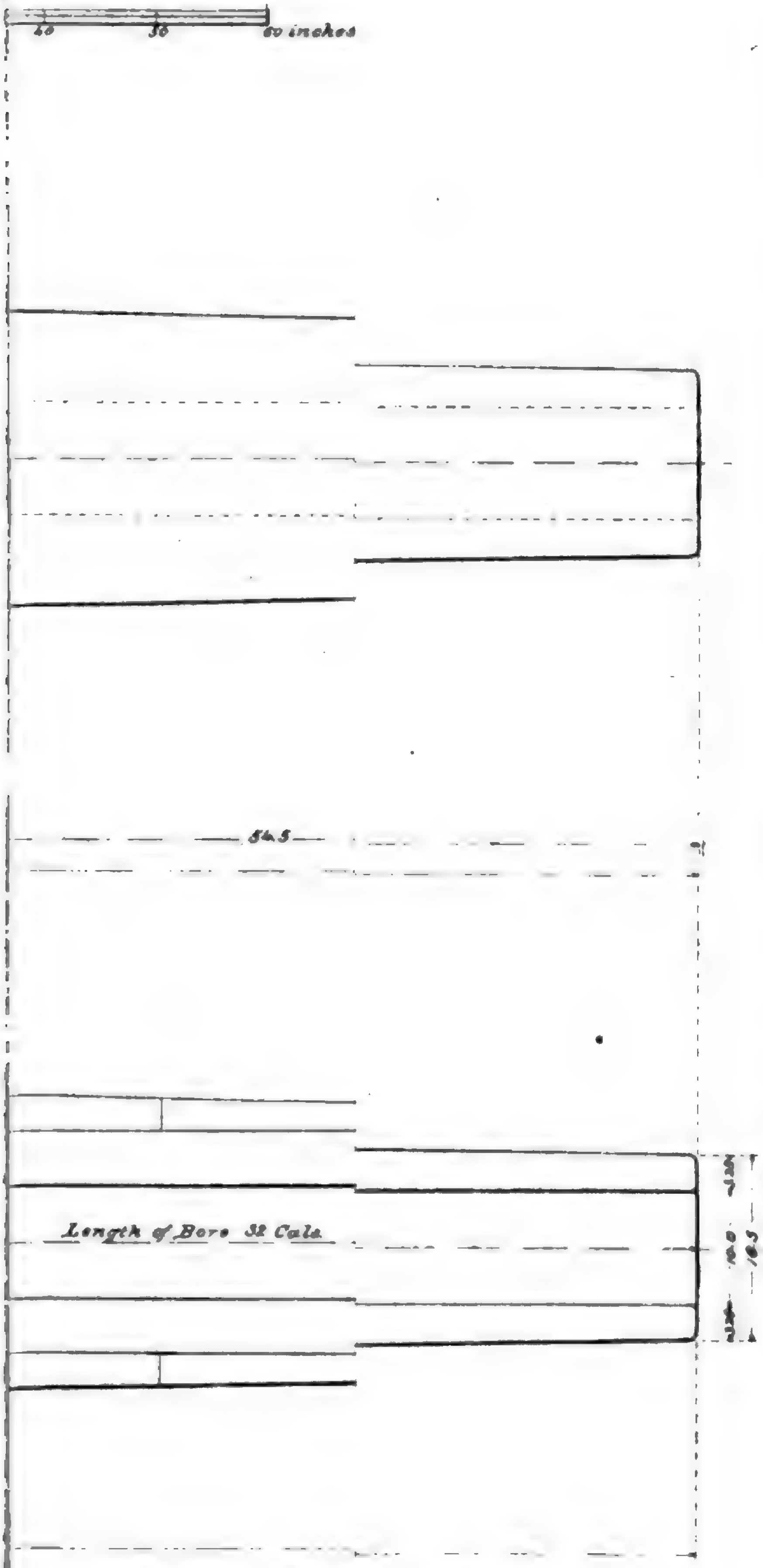
APPENDIX 38.

PROPOSED 10-INCH STEEL BREECH-LOADING RIFLE.

(1 PLATE.)

PLATE I.

L. STEEL R



-dnance,
-l Assistant

APPENDIX 39.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON OCTOBER 1, 1884.

Rank and name.	Duty.	Address.
BRIGADIER-GENERAL.		
Stephen V. Benét	Chief of Ordnance	Washington, D. C.
COLONELS.		
1. J. McAllister, brevet	Commanding the Benicia Arsenal	Benicia, Cal.
2. S. Crispin, brevet	Commanding the Ordnance Agency	Corner of Houston and Greene streets, New York. Post-office box 1811.
3. T. G. Baylor, brevet	Commanding the New York Arsenal, president of the Ordnance Board, and member of Board on Foundry for Heaviest Cannon, &c., and President of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
LIEUTENANT-COLONELS.		
1. J. M. Whittemore	On duty in the office of the Chief of Ordnance.	Washington, D. C.
2. A. R. Buffington	Commanding the National Armory	Springfield, Mass.
3. D. W. Flagler, brevet	Commanding the Rock Island Arsenal.	Rock Island, Ill.
4. A. Mordecai, brevet	Commanding the Watervliet Arsenal	West Troy, N. Y.
MAJORS.		
1. S. C. Lyford, brevet lieutenant-colonel.	Commanding the Frankford Arsenal, and President of Executive Departments Board, World's Industrial and Cotton Centennial Exhibition, 1884.	Philadelphia, Pa.
2. F. H. Parker, brevet	Commanding the Watertown Arsenal and member of Board for Testing Rifled Cannon, &c.	Watertown, Mass.
3. J. P. Farley	Commanding the United States Powder Depot.	Dover, N. J.
4. L. S. Babbitt	Commanding the Fort Monroe Arsenal.	Fort Monroe, Va.
5. W. A. Marye	Commanding the Augusta Arsenal	Augusta, Ga.
6. I. Arnold, jr	Commanding the San Antonio Arsenal.	San Antonio, Tex.
7. C. Comly	Instructor of Ordnance and Gunnery, United States Military Academy.	West Point, N. Y.
8. J. R. McGinness, brevet	Commanding the Saint Louis Powder Depot.	Jefferson Barracks, Mo.
9. G. W. McKee, brevet	Member of the Ordnance Board and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
10. F. H. Phipps, brevet	Commanding the Kennebec Arsenal	Augusta, Me.
CAPTAINS.		
1. J. W. Reilly, brevet	Commanding the Allegheny Arsenal	Pittsburgh, Pa.
2. J. A. Kress, brevet major	Commanding the Indianapolis Arsenal.	Indianapolis, Ind.
3. O. E. Michaelis, brevet	Assistant, Frankford Arsenal	Philadelphia, Pa.
4. C. E. Dutton	On duty under the Interior Department.	Geological Survey, Washington, D. C.
5. J. G. Butler	Assistant, Rock Island Arsenal	Rock Island, Ill.

Stations and duties of the officers of the Ordnance Department, &c.—Continued.

Rank and name.	Duty.	Address.
CAPTAINS—Continued.		
6. C. Bryant	Commanding the Vancouver Barracks Ordnance Depot and Chief Ordnance Officer, Department of the Columbia.	Vancouver, Washington Territory.
7. A. L. Varney	Assistant, Rock Island Arsenal	Rock Island, Ill.
8. J. C. Clifford	Assistant, Watervliet Arsenal	West Troy, N. Y.
9. J. E. Greer	Commanding the Fort Leavenworth Ordnance Depot and Chief Ordnance Officer Department of the Missouri.	Fort Leavenworth, Kans.
10. J. Pitman	Assistant, Watertown Arsenal	Watertown, Mass.
11. C. Shaler	Member of the Ordnance Board and member of Board for Testing Rifled Cannon, &c.	Governor's Island, New York City. Post-office box 1449.
12. H. Metcalfe	Assistant, Watervliet Arsenal	West Troy, N. Y.
13. W. S. Starring	Assistant, National Armory	Springfield, Mass.
14. C. S. Smith	Principal Assistant in the Ordnance Bureau.	Washington, D. C.
15. S. E. Blunt	Chief Ordnance Officer, Department of Dakota.	Fort Snelling, Minn.
16. F. Heath	Assistant, National Armory	Springfield, Mass.
17. D. M. Taylor, A. D. C	To the Commanding General Division of the Pacific.	Presidio, San Francisco, Cal.
18. D. A. Lyle	On foundry duty, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury, and Member of Board for Testing Rifled Cannon, &c.	Boston, Mass. Post-office box 2253.
19. J. Rockwell, jr	Commanding the Fort Abraham Lincoln Ordnance Depot.	Fort A. Lincoln, Dak.
20. J. C. Ayres	Assistant, Benicia Arsenal	Benicia, Cal.
FIRST LIEUTENANTS.		
1. M. W. Lyon	Assistant, Watertown Arsenal	Watertown, Mass.
2. C. W. Whipple	On duty with the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
3. A. H. Russell	Assistant, Benicia Arsenal	Benicia, Cal.
4. R. Birnie, jr	On foundry duty	Cold Spring, N. Y.
5. I. MacNutt	Assistant, Frankford Arsenal	Philadelphia, Pa.
6. C. C. Morrison	Assistant, Rock Island Arsenal	Rock Island, Ill.
7. F. Baker	Assistant, Frankford Arsenal	Philadelphia, Pa.
8. O. B. Mitcham	Commanding the Cheyenne Ordnance Depot.	Cheyenne, Wyo.
9. H. D. Borup	On foundry duty	Boston, Mass. Post-office box 2253.
10. L. L. Bruff	Assistant Instructor of Ordnance and Gunnery, United States Military Academy.	West Point, N. Y.
11. C. H. Clark	Assistant, National Armory	Springfield, Mass.
12. W. M. Medcalfe	Assistant to the Ordnance Board	Governor's Island, New York City. Post-office box 1449.
13. William Crozier	Assistant, Watertown Arsenal	Watertown, Mass.
14. W. B. Gordon	Acting Assistant Professor of Philosophy, United States Military Academy.	West Point, N. Y.
15. F. E. Hobbs	On foundry duty	Station G, Philadelphia, Pa.
16. D. A. Howard	Acting Assistant Professor of Mathematics, United States Military Academy.	West Point, N. Y.
ORDNANCE STOREKEEPERS.		
A. S. M. Morgan, captain	On duty, Allegheny Arsenal	Pittsburgh, Pa.
W. H. Rexford, captain	On duty, Indianapolis Arsenal	Indianapolis, Ind.
D. J. Young, captain	On duty, Watervliet Arsenal	West Troy, N. Y.
M. J. Grealish, captain	On duty, Augusta Arsenal	Augusta, Ga.
V. McNally, captain	On duty in the office of the Chief of Ordnance.	Washington, D. C.

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